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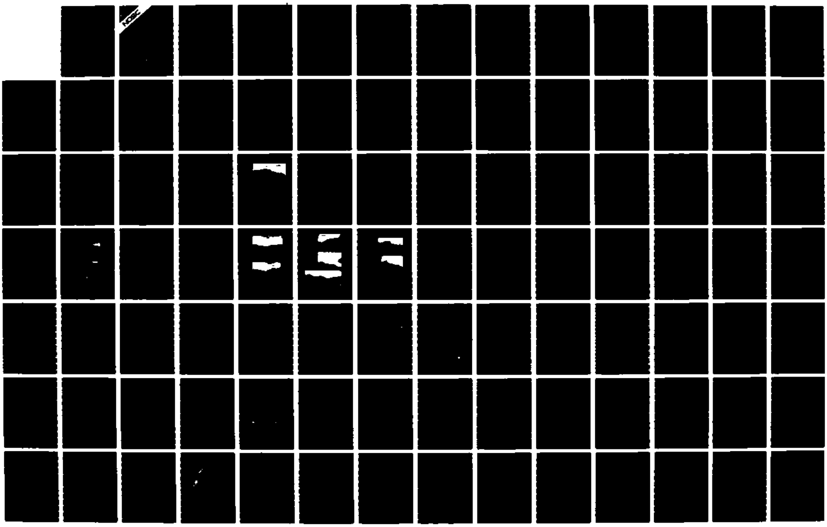

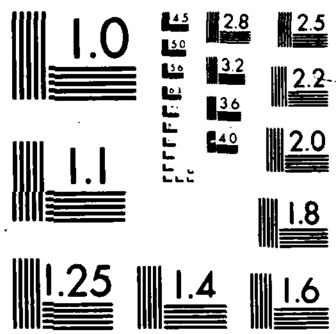
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Aerial Surveys of Endangered Whales in the Northern Bering, Eastern Chukchi, and Alaskan Beaufort Seas, 1985: With a Seven Year Review, 1979-85

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Prepared for
Minerals Management Service
Alaska Outer Continental Shelf Region
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DEPARTMENT OF THE NAVY
NAVAL OCEAN SYSTEMS CENTER

The opinions, findings, conclusions, or recommendations expressed in this report are those of the authors and do not necessarily reflect the views of the Department of the Interior, nor does mention of trade names or commercial products constitute endorsement or recommendation for use by the Federal Government of the United States.

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ADMINISTRATIVE INFORMATION

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Aerial surveys and acoustic recordings of bowhead whales and, secondarily, other marine mammals were made from mid-July 1985 through October 1985 in the northern Bering, eastern Chukchi, and Alaskan Beaufort Seas. Survey results and observations on bowhead distribution, relative abundance and density, migration patterns, general behavior, and sound production are presented. Presented here also are survey results and observations on gray whale distribution, relative abundance, and general behavior. Incidental sightings of all marine mammals are reported.

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EXECUTIVE SUMMARY

This report summarizes the 1985 investigations of the distribution, abundance, migration timing, habitat relationships, and behavior of endangered whales in the northern Bering, eastern Chukchi, and Alaskan Beaufort Seas. Data presented herein were collected during transect and search aerial surveys flown in a specially modified Grumman Goose in the study region from 17 July through 23 October. These data are subsequently compared to the results of previous (1979-84) studies.

One hundred thirty-nine sightings of 705 gray whales (Eschrichtius robustus) were made in the northern Bering Sea and the northeastern Chukchi Sea in July. Two calves were seen with a total of 477 gray whales in the northern Bering Sea, resulting in a gross annual recruitment rate (GARR) of 2/477 or 0.42 percent. Fifteen calves were seen in a total of 228 whales in the Chukchi Sea, resulting in a GARR of 6.58 percent. Most grays (66%) appeared to be feeding. Whales not feeding were either swimming (26%), part of a cow/calf association (5%) or resting (3%). Swimming direction was not significantly clustered about any heading. Over six seasons (1980-85), 853 sightings of 2490 gray whales have been made in summer. Areas of greatest gray whale density were the Chirikov Basin north of Saint Lawrence Island (0.360 whales/km^2) and the coastal Chukchi Sea between Point Hope and Barrow (0.261 whales/km^2). In summer, more gray whales were seen feeding (52%, n = 1291) than any other single activity; swimming direction was not significantly clustered around any heading. The ratio of gray whale calves to all whales (GARR = no. calves/total no. whales) was significantly higher in the Chukchi Sea (44/553 = 0.08) than in the northern Bering Sea (6/1935 = 0.003; $X^2 = 128.3$, $p < 0.001$). The relative abundance of gray whale calves was also significantly higher in the Chukchi Sea (0.39 calves/survey hour) than in the northern Bering Sea (0.005 calves/survey hour; $X^2 = 41.23$, $p < 0.001$) indicating that gray whales maintain patterns of reproductive-class segregation on the northern range.

Seventy-seven sightings of 139 bowhead whales (Balaena mysticetus) were made during August, September, and October 1985 in the Alaskan Beaufort and northeastern Chukchi Seas. Survey effort and all bowhead sightings are depicted in daily flight maps presented in Appendix A. Fewer bowheads (n = 12) were seen in August than in the previous three years (n = 19, 1984; n = 59, 1983; n = 145, 1982). Whales seen in August maintained headings in all directions and were seen in water

16 to 146 m deep. Sixty-seven bowheads were seen in September, similar to numbers seen in 1979 (n = 60), 1980 (n = 34) and 1983 (n = 78), but far below the number seen in 1981 (n = 232), 1982 (n = 301) and 1984 (n = 260). Whales seen in September were in water 7 to 57 m deep and maintained westerly headings. In October, 57 bowheads were seen in the Alaskan Beaufort Sea and three were sighted in the northeastern Chukchi Sea. Bowheads in October were in water 7 to 595 m deep, and also maintained mostly westerly headings.

Over seven survey seasons (1979-85), 957 sightings of 1712 bowheads have been made from August through October. In August, bowheads were seen in the eastern Alaskan Beaufort Sea extending as far west as 147°W. In September and October, bowheads were distributed across the Alaskan Beaufort Sea and overlapped some OCS oil and gas lease areas within the Beaufort Sea Planning Area. The derivation of bowhead density estimates for 1979-85 are presented in Appendix B. Overall, highest monthly bowhead densities were calculated for subregion D5 in August (0.130 whales/km^2), subregion A2 in September (0.912 whales/km^2) and subregion B3 in October (0.580 whales/km^2).

The observed 1985 bowhead migration period extended from 22 September to 20 October, a shorter time period than any previous year. Bowheads were seen in the Alaskan Beaufort Sea as early as 7 August, but except for one whale swimming west near Demarcation Bay on 17 August, bowheads seen prior to 22 September did not appear to be migrating. Peak daily abundance indices (i.e., WPUE = no. whales/hour of survey effort) during the migration occurred on 27 September (4.80), 6 October (5.23) and 13 October (2.99). The status of the bowhead whale migration in the eastern Alaskan Beaufort Sea was monitored from 7 to 27 September by researchers on an additional aircraft. Data were supplied daily to these researchers to advise them of bowhead distribution and movements derived via transect surveys. The results of these monitoring surveys are summarized in Appendix C.

The axis of the 1985 bowhead migration, as defined by median depth at sightings made on random transects, was the 29 m isobath. This axis was similar to all other years, except 1983 when the median depth at random bowhead sightings during the migration was 145 m ($U = 464$, $p \leq 0.001$). Peak 5-day SPUE (SPUE = no. bowhead sightings/hour of survey effort) was earlier in years of heavy ice coverage (1980, 1983) than in years of light ice coverage (1979, 1981, 1982, 1984). The peak 5-day SPUE in 1985, a year of moderate ice coverage due to a mid-September

storm, was later (11-15 October) than for any other year. Ice coverage was negatively correlated with peak WPUE ($r = -0.849$, $p < 0.02$), SPUE peak (-0.568, $p < 0.05$) and the percentage of whales observed feeding ($r = -0.607$, $p < 0.05$). Ice coverage may also limit the ability of observers to see surfaced whales at greater distances from the survey trackline as ice coverage was negatively correlated with sighting distance in 1982 ($r = -0.299$, $p < 0.001$) and 1983 ($r = -0.260$, $p < 0.05$), and for the combined data of 1981-85 ($r = -0.224$, $p < 0.001$). The combined data of 1981-85 indicated that bowheads were seen in relatively lighter ice coverage (40%) than overall average ice conditions recorded during random transect surveys (51%; $t = 4.85$, $p < 0.001$). Bowheads were more often observed involved in social behaviors (56%) than migrating (44%) in 1985, similar to 1982 and 1984. Fewer bowhead calls were recorded in 1985 than any year since 1982, but call rate was higher than for any year but 1983. Overall, recorded bowhead call rate was found to be significantly higher in September-October ($\bar{x} = 23.13$ calls/wh-h) than in April-May ($\bar{x} = 9.91$ calls/wh-h; $t' = 2.29$, $p < 0.05$), or August ($\bar{x} = 5.59$ calls/wh-h; $t' = 3.17$, $p < 0.005$). The call rate during the heavy ice year of 1983 (11.3 calls/wh-h) was nearly an order of magnitude greater than the average call rate of all other years since 1982 ($\bar{x} = 1.3$ calls/wh-h). The occurrence of significant correlations between call types suggests that call production changes with concomitant behavior. Seven bowhead calves were seen during fall 1985 resulting in a gross annual recruitment rate (GARR) of 7/139 or 5 percent, the same as that for 1982, but higher than all previous years except 1983 (8%).

Belukha whales, some groups with calves, were seen in the Alaskan Beaufort and northeastern Chukchi Seas throughout the fall. Belukhas were distributed further offshore over deeper water ($\bar{x} = 446.5$ m) than bowhead whales ($\bar{x} = 56.2$ m; $t = 5.1$, $p < 0.001$). Bearded seals and one ringed seal were seen in the latter half of the fall season. Walrus were seen only in the Chukchi Sea in July before the ice moved offshore. Polar bears were seen on the ice in late September and October.

An erratum to the 1979-85 bowhead and gray whale data base appears in Appendix D. Refinement of aerial-survey techniques, and microcomputer application to data collection and analysis have caused some changes to original raw data reported in past year NOSC Technical Reports and Documents.

Aerial surveys of endangered whales in the Navarin and Saint Matthew-Hall OCS Planning Areas were conducted in June 1985 and January 1986. The methodologies and results of these surveys are presented independently as Appendix E.

ACRONYMS AND ABBREVIATIONS

ADFG	Alaska Department of Fish and Game
AM	Amplitude Modulated
AMP	A Mapping Package
ASA	American Standards Association
BE	Belukha Whale
BH	Bowhead Whale
BS	Bearded Seal
CIDS	Concrete Island Drilling Structure
CPUE	Calves Per Unit Effort
CT	Unidentified Cetacean
FM	Frequency Modulated
GARR	Gross Annual Recruitment Rate
GNS	Global Navigation System
GW	Gray Whale
IDL	International Date Line
IWC	International Whaling Commission
MMS	Minerals Management Service
NMFS	National Marine Fisheries Service
NOAA	National Oceanographic and Atmospheric Administration
NOSC	Naval Ocean Systems Center
NTIS	National Technical Information Service
OCS	Outer Continental Shelf
PN	Unidentified Pinniped
PR	Polar Bear
RS	Ringed Seal
s.d.	Standard Deviation
SPUE	Sightings Per Unit Effort
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
VHF	Very High Frequency
WPUE	Whales Per Unit Effort
WS	Walrus

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INTRODUCTION

The Naval Ocean Systems Center (NOSC), San Diego, California has been funded by the Alaska Outer Continental Shelf (OCS) area office of the Minerals Management Service (MMS), U.S. Department of the Interior since 1979 to conduct aerial surveys of endangered whales and other marine mammals in the northern Bering (above 63° N), eastern Chukchi, and Alaskan Beaufort Seas. As part of its responsibilities under the OCS Lands Act, National Environmental Policy Act, Marine Mammal Protection Act, and Endangered Species Act, MMS has continued this work as an extension of previous studies (Ljungblad et al., 1980; Ljungblad, 1981; Ljungblad et al., 1982, 1983, 1984a, 1985b). Results of these studies have been useful to MMS in preparing environmental impact statements and in making decisions relative to the leasing, exploration, and development of the Alaskan OCS.

The bowhead whale (Balaena mysticetus) has been the principal species investigated over the past seven years. Historically, bowheads had a nearly circumpolar distribution north of 60° N. However, a long history of exploitation seriously reduced the number of bowhead whales in each of five geographically separate stocks (Breiwick et al., 1981; Bockstoce and Botkin, 1983). The western Arctic stock, estimated by the International Whaling Commission (IWC) to contain 4,417 whales (IWC, 1986), is the population monitored in this study.

Gray whales (Eschrichtius robustus) have also been investigated during this study. Principal areas surveyed are the summer feeding grounds in the northern Bering Sea and eastern Chukchi Sea (Bogoslovskaya et al., 1981; Nerini, 1984; Moore et al., 1986b), and the northeastern Chukchi Sea (Moore et al., 1986a). This population is now estimated to number 17,577 $\pm$ 2,364 grays (Reilly et al., 1983).

This report is a summary of 1985 field results on aerial surveys of bowhead whale distribution, relative abundance, density, migration, and behavior in accordance with the objectives as outlined below. Gray whale distribution, relative abundance, density, habitat relationships and behavior are also reported, as well as incidental information on all other marine mammals seen. Synthesis and comparison of 1985 data with the results of previous years are provided in a brief conclusion section at the end of the report. A flight track and descriptive caption for each flight are presented in Appendix A. The distribution of 1985 survey effort and observed densities of bowhead and gray whales with comparisons to data collected from 1979 through 1984 are presented in Appendix B.

Objectives

The primary objectives of the 1985 surveys, as stated in the Inter-Agency Agreement Statement of Work, were to:

- o Determine seasonal distribution, migration routes, relative abundance, and habitat characteristics of endangered whales in or near existing and proposed federal lease sales in the northern Bering, Chukchi, and Beaufort Seas
- o Derive estimates and indicators of relative and/or absolute abundance of endangered whales in these areas
- o Describe behavioral characteristics of endangered whales observed in these areas
- o Deploy sonobuoys to detect sounds produced by whales, to be used as additional indices of whale presence in these areas
- o Obtain distributional information on nonendangered marine mammal sightings incidental to other investigations
- o Consult and coordinate field activities with other Federal agencies, state or local government organizations, or other endangered species researchers to maximize productivity of this study and minimize conflict with other resource uses

In conjunction with the primary survey objectives, corollary objectives specific to the fall season were to:

- o Summarize daily survey efforts, bowhead sightings and behavior, and survey conditions
- o Collate bowhead distribution and movement data from additional MMS-funded and industry-funded projects, and reformat to NOSC-format data file
- o Provide comprehensive daily reports from the field base of operations via phone modem to the Anchorage MMS office, including data from all projects on bowhead distribution, behavior, movement, and habitat relationships.

These reports were provided to government officials responsible for regulating offshore drilling and geophysical exploration, and for protection of endangered species (Minerals Management Service and National Marine Fisheries Service (NMFS) respectively).

An additional secondary research team and survey aircraft were dedicated for the period 7-27 September 1985 in the Beaufort Sea to:

- o Monitor the status of the bowhead whale migration
- o Describe the general behavior and sound production of observed whales

The results of these efforts are discussed in relation to the primary study and are summarized and tabulated in Appendix C.

METHODS AND MATERIALS

Study Area and Aerial Survey Procedures

The study area included the Bering Sea from north of St. Lawrence Island (63° N) to 65°59'N, the Chukchi Sea north of 66°N and east of the International Date Line (IDL, 168°58' W) to 157°W, and the Alaskan Beaufort Sea from 157°01'W east to 140° W and offshore to 72° N. This study area was divided into survey blocks (Figure 1) suitable to line transect surveys (one or, with favorable conditions, two blocks could be surveyed completely on one flight). The Alaskan Beaufort Sea comprised blocks 1 to 12, the Chukchi Sea blocks 13 to 24, and the northern Bering Sea blocks 25 to 29.

Two types of aerial surveys were utilized to accomplish the objectives listed:

1. Line transect surveys were flown in survey blocks to determine distribution and estimate relative and absolute abundance. Line transect is one available survey method from which statistical inferences can be made, provided the starting and turning points of the line are selected randomly (Cochran, 1963). Survey blocks were divided into sections that were 30 minutes of longitude or 10 minutes of latitude wide, and each section divided into 10 equal segments. Starting and/or turning points were chosen within each section by selecting two numbers from a random numbers' table and matching them to the numbered segments. A transect line was then drawn between the two segments. The same procedure was followed for each section of the survey block, and all transect lines were then linked together with connecting lines at top and bottom.

2. Search surveys were flown to locate whales and observe their behavior, or when transiting to a new base of operations. These surveys did not follow a preset paradigm, but instead were dependent upon our previous patterns of whale sightings (i.e., number, heading, swimming speed), weather, sea state, and ice conditions.

The year was divided into two seasons: summer (July), and fall (August, September, October). Bases of operation were Kotzebue, Barrow, and Deadhorse, Alaska.

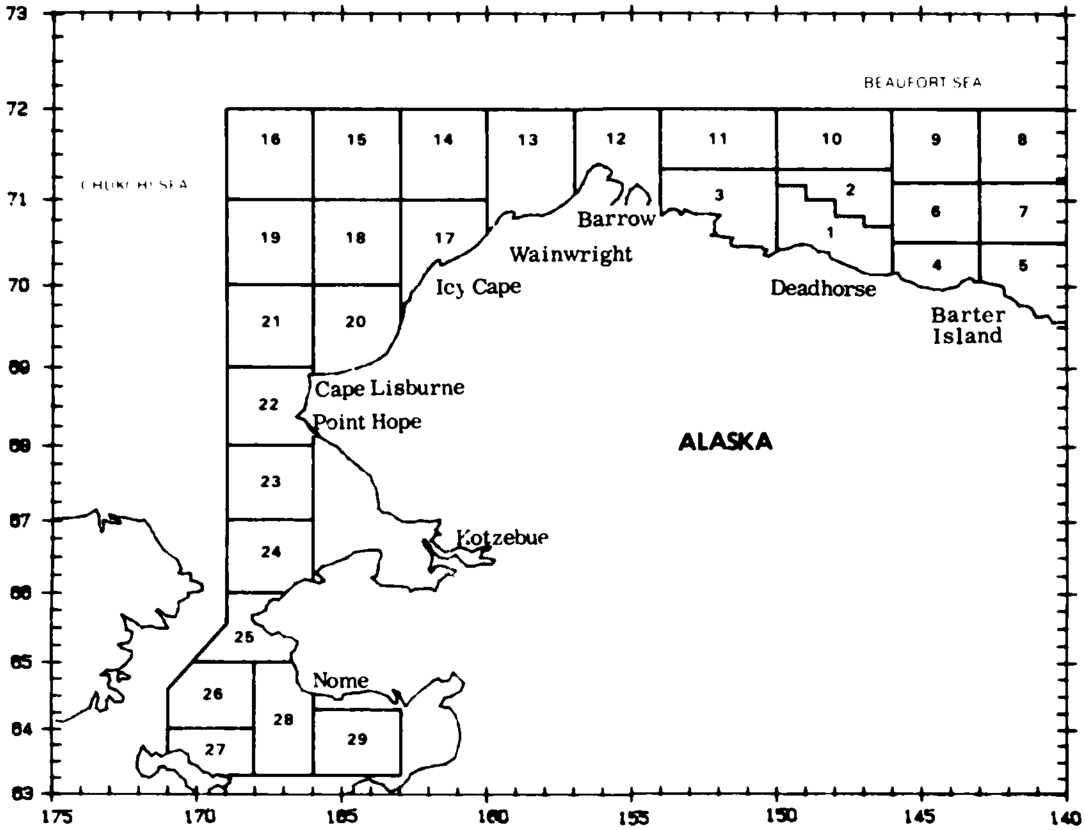


Figure 1. Study area and transect blocks.

Equipment, Data Collection, and Analyses

The aircraft used for the surveys was a Grumman Turbo Goose model G21G with a call sign of N780 provided by the Office of Aircraft Services, U.S. Department of Interior, Anchorage. The aircraft was equipped with a Global Navigation System (GNS) 500 that provided continuous position updating (0.6 km/survey hour, precision) and transect turning point programming. Surveys were flown at 100 m to 458 m altitude, at speeds of 222 to 296 km/hr. Higher altitudes were maintained when weather permitted to maximize visibility and to minimize disturbance to marine mammals. The aircraft's maximum time aloft was 6.5 hrs.

The aircraft cockpit was outfitted with four seats, each of which afforded excellent visibility through large side windows for the pilot, co-pilot and two principal observers. The pilots acted as limited observers. A long rectangular window behind the cockpit provided good visibility for an observer-recorder.

Table 1. Data entry sequence on portable flight computer.

	1.	**Entry number**	
	2.	**Time**	
	3.	**Latitude**	
	4.	**Longitude**	
	5.	**Altitude**	
	6.	**Reason for entry**	
Position/environmental update (13-key)	7.	**Survey type (flag)**	
	8.	Weather	
	9.	Visibility right	
	10.	Visibility left	Sighting update (20-key)
	11.	Ice coverage	
	12.	Ice type	
	13.	Sea state	
	14.	Water color	**Rapid sighting update (9-key)**
	15.	Water depth	
	16.	**Species**	
	17.	Clinometer angle	
	18.	Sighting cue	
	19.	Behavior	
	20.	**Total number**	
	21.	Estimated size class	
	22.	Total number calves	
	23.	Swim direction	
	24.	Estimated swim speed class	
	25.	Response to aircraft	
	26.	Repeat sighting	
	27.	Photo roll number	
	28.	Photo frame numbers	

Each observer had a clinometer to take angles on all whale sightings abeam of the aircraft which, along with altitude, can be used to compute animal distance from the survey track line. All observers and the pilots were linked into the same communication system, and commentary on the aircraft could be recorded.

A portable computing system (Hewlett-Packard 85) was used aboard the aircraft to store and later analyze the flight data. The computer was interfaced to the GNS for automatic input of entry number, time, latitude, and longitude, and to the radar altimeter for precise input of altitude. One of four different data entry formats was selected on the computer depending on the reason for entry. Whenever possible, a 28-key entry format was used when whales were seen (Table 1). An abbreviated 20-key sighting update format was used when several

whales were sighted within a short period of time. An even shorter rapid sighting update (9-key format) was used in areas of extremely high animal concentrations to avoid the lumping of sightings. A position update 13-key format, including data on weather, visibility, ice coverage, and sea state, was entered at turning points, when environmental conditions changed, or, in the absence of sighting data, every 10 minutes. All entries were coded as to the type of survey being conducted (Table 1: Entry no. 7). During a typical flight (Figure 2), a search leg was flown to the survey block, followed by a series of random transect legs that were joined together by connect legs, with search leg(s) conducted back to the base of operations. Sea state was recorded according to the Beaufort scale outlined in Piloting, Seamanship, and Small Boat Handling (Chapman 1971). Ice type was identified using terminology presented in the Naval Hydrographic Office Publication Number 609 (1956), and ice coverage was estimated in percent.

Sonobuoys, passive listening systems that contain hydrophone arrays and VHF transmitters, were dropped near whales whenever possible in an attempt to collect acoustic data. Models AN/SSQ-57A and AN/SSQ-41B, with frequency responses of 10 Hz to 20 kHz, were used. Sonobuoys are designed to be dropped from the aircraft and their descent is slowed by means of a rotochute or parachute. Once in contact with water, the unit is energized by a saltwater-activated battery. At that time the roto/parachute assembly is jettisoned and the hydrophone array drops to a preselected depth of 18.2 or 91.4 m. The 18.2 m depth setting is most commonly used. The sounds picked up by the hydrophones are then amplified and transmitted to a VHF broadband receiver aboard the aircraft. This output is recorded on a Nagra IV SJ recorder that has a frequency response within 2 dB from 25 Hz to 10 kHz, at a recording speed of 9.5 cm/s. This recorder has two channels, permitting simultaneous recording of the waterborne sounds and the observers' verbal comments.

Attempts were made to photograph as many bowhead whales as possible. Still photographs were made with hand-held 35-mm cameras (Olympus OM-1) with 210-mm or 230-mm lenses using ASA 64 or ASA 200 film at as fast a shutter speed as possible. The altitude of the aircraft and the photograph roll and frame number were noted and stored on the computer.

Bowhead, gray, and belukha whale distributions were plotted by month and season. Bowhead distribution was also plotted in relation to OCS drilling sites that were active in 1985. In addition, a comprehensive bowhead distribution analysis incorporating data from ten survey aircraft is presented. An index of relative

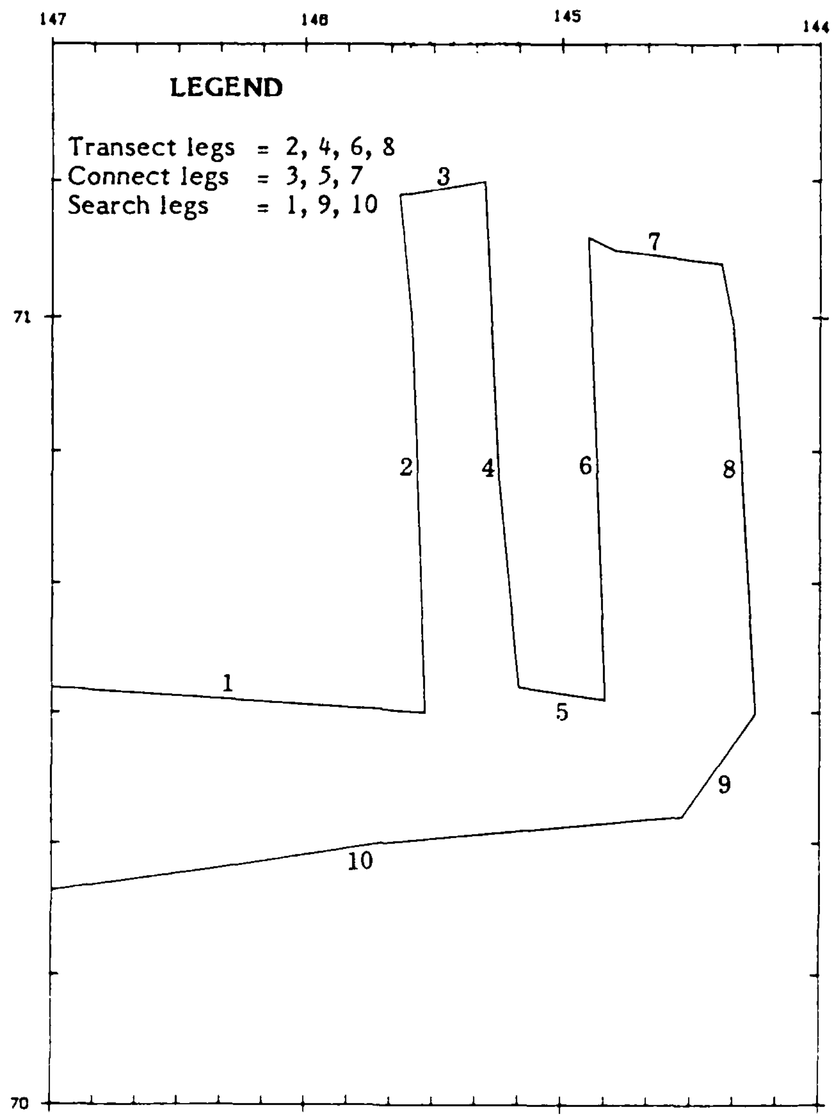


Figure 2. Example flight track delineating transect, connect and search survey legs.

abundance was derived as whales per unit effort (WPUE = no. whales/hours of survey effort) per survey block. Bowhead and gray whale density estimates were derived for survey blocks using strip transect methodologies (Estes and Gilbert, 1978). All whale sightings were entered into the distribution and relative abundance analyses, regardless of the type of survey leg being conducted when the sighting was made. Therefore, distribution scattergrams and WPUE represent the total bowhead sighting data base in relation to the total survey effort. Density estimates, on the other hand, require that sightings used in their derivation be collected at random (Cochran, 1963). Therefore, only sightings made on random transect legs were used to derive density estimates; if no sightings were made on random transects within a survey block, density was not calculated for that block.

In addition to the survey block analysis, density estimates were also derived for subregions reflecting bathymetrically stratified OCS lease sale planning areas and are presented, with a description of density estimate methodologies, in Appendix B.

The timing of the 1985 migration was analysed as WPUE/date, and habitat preference as percentage of whales/ice class and percentage of whales/depth regime. Directionality of whale headings was analyzed using Rayleigh's test (Batschelet, 1972). The 1979-85 bowhead sighting data base was analysed for potential shifts in migration route, and for changes in migratory timing in relation to concommitant ice coverage. The annual median water depth at bowhead sightings made on random transect legs was analysed for potential shifts in the migration route, following the protocol specified in Houghton et al. (1984). Average annual ice coverage, derived from observations made during random transect surveys, was compared to annual median depth via regression analysis. The annual timing of the 1979-85 bowhead migrations was analysed as sightings per unit effort (SPUE = no. sightings/hours of survey effort) per five-day period, from August through October. The percentage of ice coverage was averaged over five-day periods and compared to the SPUE by regression analysis. The probability of detecting bowheads during the 1979-85 fall migrations was estimated by analysing the effect of surface conditions (ie. ice coverage and sea state) on the sighting distance of surfaced bowheads from the survey track line; and, by calculating the probability that a whale will be at the surface and within an observer's field of view after the methodology outlined in Davis et al. (1982). Additional statistical comparisons, correlations and regressions were performed as appropriate (Zar, 1984).

Bowhead behaviors were classified by means of operational definitions (Table 2). Behaviors were grossly catalogued into two types for purposes of discussion: migratory behaviors, which included swimming and diving; and social behaviors (typically observed in groups) such as milling, feeding, mating, cow-calf association, resting, and displaying. Displays included breaches, spy-hops, tail and flipper-slaps, rolls, and underwater blows. Swimming speed was subjectively estimated by observing the time it took a whale to swim one body length. An observed swimming rate of one body length/min corresponded to an estimated speed of 1 km/hr, one body length/30s was estimated at 2 km/hr, and so on. Swimming speed and whale size were recorded by relative category (i.e., still, 0 km/hr; slow, 0-2 km/hr; medium, 2-4 km/hr; or fast, 4 km/hr; and calf, immature, adult, or large adult respectively) rather than on an absolute scale.

Table 2. Operational definitions of observed bowhead whale behaviors.

MIGRATORY:	
Swimming	Forward movement through the water propelled by tail pushes.
Diving	Change of swimming direction or body orientation relative to the water surface resulting in submergence; may or may not be accompanied by lifting of the tail out of the water.
SOCIAL:	
Milling	Whales swimming slowly near one another in close proximity (within 100 m) at the water surface.
Feeding	Whale/whales diving repeatedly in the same general area sometimes accompanied by mud streaming from the mouth and defecation upon surfacing; nearly synchronous diving and surfacing have been noted as have echelon formation surface feeding with swaths of clearer water noted behind the whales and open mouth surface swimming.
Mating	Ventral-ventral orientation of a pair of whales often with at least one other whale present to stabilize the mating couple; often within a group of milling whales; pairs appear to hold each other with their pectoral flippers and may entwine their tails.
Cow-Calf	Calf nursing; calf swimming within 20 m of an adult.
Resting	Whale/whales at the surface with head, or head and back exposed, showing no movement: more commonly observed in heavy ice conditions than in open water.
Displaying:	
Rolling	Whale rotating on longitudinal axis, sometimes associated with mating.
Flipper-Slapping	Whale on its side striking the water surface with its pectoral flipper one or many times; usually seen in groups, sometimes when slapping whale is touching another whale.
Tail-Slapping	Whale hanging horizontally or vertically in the water with tail out of water waving back and forth striking the water surface; usually seen in groups.
Spy-Hopping	Whale rising vertically from the water such that the head and up to one-third of the body, including the eye, is exposed; usually seen in groups.
Breaching	Whale exiting vertically from the water such that half to nearly all of the body is exposed then falling back into the water, usually on its side, creating a large splash and presumably some sounds.
Underwater Blow	Exhalation of breath while submerged creating a visible bubble.

In compliance with condition B.4-6 of permit No. 459 to "take" endangered marine mammals, any sudden overt change in whale behavior observed coincident with the arrival of the survey aircraft was recorded (and later reported) as "response to aircraft," although it was impossible to determine the specific stimulus for the behavioral change. Such changes included abrupt dives, sudden course diversion,or cessation of behavior ongoing at first sighting.

RESULTS AND DISCUSSION

SUMMER (17 to 31 July)

Survey Effort, Rationale, and Sighting Summary

Forty-seven and one-third hours of surveys were flown in July, with 10 percent (4.8 hrs) of this effort in the northern Bering Sea, 72 percent (34.0 hrs) in the northeastern Chukchi Sea, and 18 percent (8.5 hrs) in the Alaskan Beaufort Sea (Table 3, Figure 3). This effort represents more coverage of the northern Bering Sea and northeastern Chukchi Sea and less coverage of the Alaskan Beaufort Sea than in 1984, but is similar to other years. Search surveys were flown only when transect surveys were aborted due to poor weather, or during transits to a new base of operations. Inclement weather, mostly fog, prevented flying on two of the 15 days.

Surveys in the northern Bering and northeastern Chukchi Seas were designed to investigate gray whale distribution and relative abundance in near-shore and offshore waters. Survey effort was allocated to the eastern Alaskan Beaufort Sea in July to investigate the timing and location of earliest bowhead arrival in those waters and to document ice conditions.

One transect survey was flown in the northern Bering Sea. Gray whales were seen throughout blocks 25 and 26 in the Chirikov Basin, where they have been routinely observed each year since 1980, except 1984 (Ljungblad et al., 1985b). Eight transect surveys were flown and grays were seen near-shore in the northeastern Chukchi Sea. Two transect and two search surveys were flown in the Beaufort Sea, with belukhas the only cetaceans seen.

Table 3. Summary of flight effort, summer 1985.

Flight	Date	Sea	Transect Length (km)	Search Length (km)	Connect Length (km)	Total Length (km)	Time on Transect (hr:min)	Total Time (hr:min)	WPUE (Whales/hr)
1	17 July	Bering	981	34	263	1278	3:41	4:50	98.76
		Chukchi	0	146	0	146	0:00	0:27	2.22
2	18 July	Chukchi	606	341	94	1041	2:08	4:07	3.88
3	19 July	Chukchi	272	625	24	921	0:57	3:26	16.62
		Beaufort	0	10	0	10	0:00	0:04	0.00
4	20 July	Chukchi	871	189	137	1197	3:13	4:26	2.71
		Beaufort	0	13	0	13	0:00	0:03	0.00
5	21 July	Chukchi	571	136	73	780	2:00	2:43	0.00
6	22 July	Chukchi	652	311	82	1045	2:20	3:39	0.27
7	23 July	Chukchi	811	455	131	1397	2:58	4:59	0.40
8	24 July	Chukchi	820	772	152	1744	2:52	5:58	12.73
9	25 July	Chukchi	733	157	103	993	2:31	3:25	18.42
10	26 July	Chukchi	0	240	0	240	0:00	0:51	0.00
		Beaufort	0	304	0	304	0:00	0:57	0.00
11	28 July	Beaufort	580	405	83	1068	2:04	3:42	0.00
12	29 July	Beaufort	41	285	0	326	0:08	1:10	0.00
13	30 July	Beaufort	367	291	65	723	1:17	2:34	0.00
Total Bering Sea			981	34	263	1278	3:41	4:50	98.76
Total Chukchi Sea			5336	3372	796	9504	18:59	34:01	6.70
Total Beaufort Sea			988	1308	148	2444	3:29	8:30	0.00
Grand Total			7305	4714	1207	13226	26:09	47:21	14.88

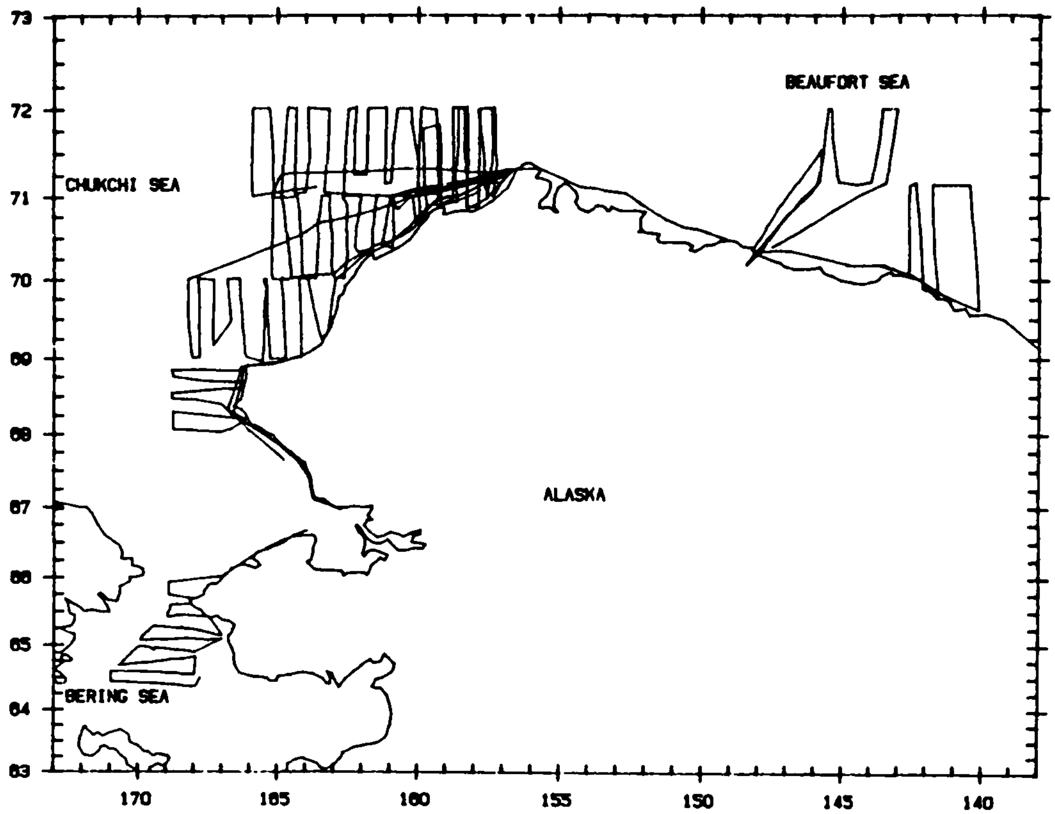


Figure 3. Composite flight track from 13 flights, summer 1985.

Survey Conditions Summary

Weather conditions in July were generally perfect for surveying. Clear skies with unlimited visibility persisted throughout most of this period, and few surveys had to be aborted or truncated due to inclement weather.

Ice in the northeastern Chukchi Sea in mid-July was heavy ($\geq$95 %) in the offshore areas, beginning 100 km offshore at Icy Cape, 60 km offshore at Wainwright and 20 km offshore at Pt. Barrow (Figure 4). Medium (30-60%) and light ice coverage or open water ($\leq$10 %) existed inshore and south of the heavy

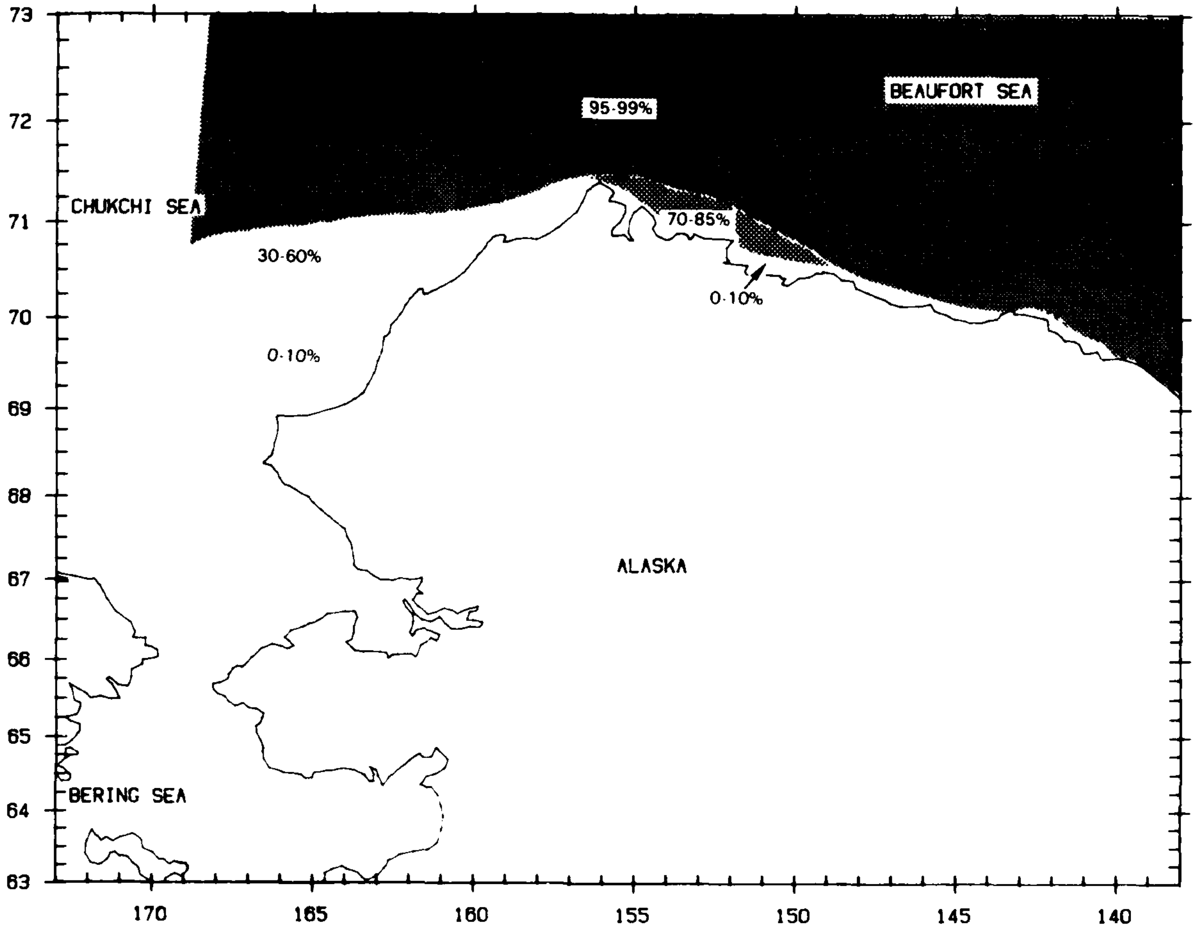


Figure 4. Schematic representation of ice conditions in the Chukchi and Beaufort Seas, summer 1985.

ice. In the Alaskan Beaufort Sea in late July, 90 to 95 percent broken floe ice coverage extended to the barrier islands east of Prudhoe Bay. West of Prudhoe Bay, ice coverage near-shore was 70 to 85 percent broken floe, increasing to 90 to 95 percent coverage 35 km offshore.

Sea state ranged from Beaufort 0 to 3 on all summer surveys.

Table 4. Summary of sightings (number of sightings/number of animals), summer 1985.

Flight	Date	Gray Whale	Belukha	Bearded Seal	Ringed Seal	Walrus	Unidentified Pinniped
1	17 July	67/478	0	0	0	1/1	5/10
2	18 July	3/16	0	0	1/2	0	2/3
3	19 July	17/57	1/3	3/3	1/1	0	0
4	20 July	7/12	1/30	2/2	0	4/155	0
5	21 July	0	0	0	0	0	0
6	22 July	1/1	0	1/1	0	2/580	0
7	23 July	1/2	0	4/6	1/1	64/4166	4/4
8	24 July	24/76	0	13/19	9/13	22/1417	23/56
9	25 July	19/63	1/1	4/5	2/2	3/33	7/9
10	26 July	0	0	0	0	0	4/4
11	28 July	0	0	0	0	0	0
12	29 July	0	0	0	0	0	0
13	30 July	0	1/3	1/1	0	0	0
TOTAL		139/705	4/37	28/37	14/19	96/6352	46/86

Gray Whale (Eschrichtius robustus)

Distribution, Relative Abundance, and Density

One hundred thirty-nine sightings of seven hundred and five gray whales were made in the northern Bering and northeastern Chukchi Seas in July (Table 4, Figure 5). Four hundred seventy-seven whales, including two calves, were seen in the northern Bering Sea on one flight (Figure 5A). Two hundred twenty-eight whales, including fifteen calves, were seen in the Chukchi Sea on eight flights (Figure 5B). The distribution of gray whales in both seas was very similar to past years.

Areas of greatest relative abundance in the Bering Sea were blocks 25 and 26 where WPUE was 46.34 and 164.25 respectively (Table 5). In the Chukchi Sea, areas of greatest abundance were blocks 13, 17, 20 and 22 where WPUE were 14.23, 12.34, 2.81, and 7.73 respectively (Table 5). Whales in block 22 were approximately 7 to 26 km south of Pt. Hope. Those seen in blocks 13 and 17 were

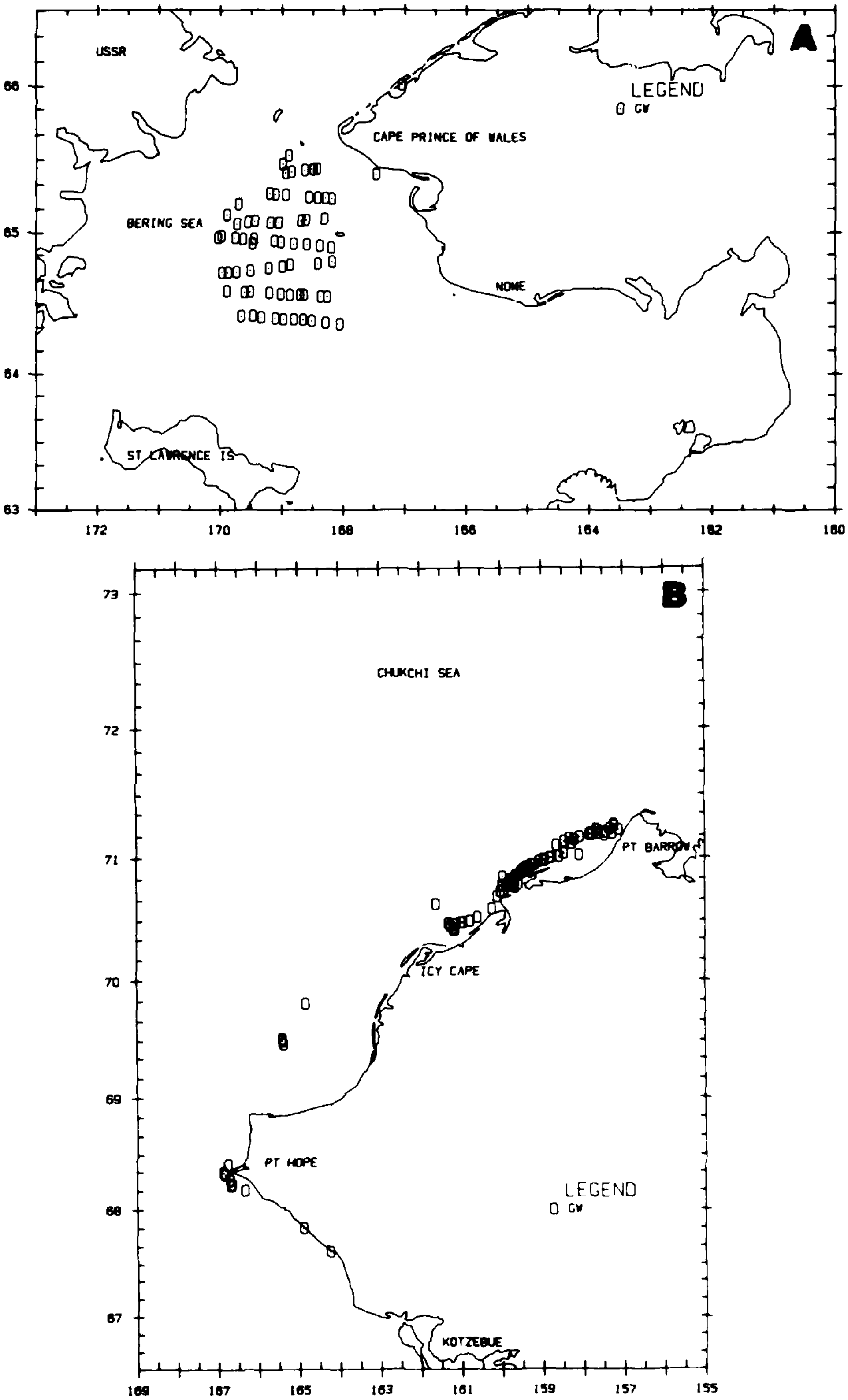


Figure 5. Distribution of 139 sightings of 705 gray whales, summer 1985: 66 sightings of 477 whales, Bering Sea (A); 73 sightings of 228 whales, Chukchi Sea (B).

Table 5. Relative abundance (WPUE) of gray whales by survey block, summer 1985. WPUE = no. whales/hours of survey effort

Block	Flights*	Hours	Gray Whales	WPUE
1	4	1.19	0	0.00
2	2	0.71	0	0.00
3	1	0.52	0	0.00
4	1	0.64	0	0.00
5	1	1.61	0	0.00
6	1	0.49	0	0.00
7	1	1.20	0	0.00
9	2	1.64	0	0.00
12	6	0.51	0	0.00
13	8	9.77	139	14.23
14	5	3.25	0	0.00
15	2	3.22	0	0.00
17	6	3.81	47	12.34
18	3	2.90	0	0.00
19	1	0.33	0	0.00
20	3	2.85	8	2.81
21	1	1.91	0	0.00
22	3	3.88	30	7.73
24	1	0.17	1	5.88
25	1	2.46	114	46.34
26	1	2.21	363	164.25
28	1	0.16	0	0.00
Unblocked	8	1.92	3	1.56
Total/Average	63	47.35	705	14.89

*Flight is any traverse of a block.

generally within 30 km off shore between Icy Cape and Pt. Barrow, and those seen in block 20 were north of Cape Lisburne, within 90 km of shore. One whale was seen in block 24 less than one kilometer from shore.

Estimates of gray whale density/block ranged from 0.0936 whales/km^2 in block 26 to 0.0008 whales/km^2 in block 20 (Figure 6). Density estimates for blocks 25, 13 and 17 were 0.0394 whales/km^2, 0.0018 whales/km^2 and 0.0034 whales/km^2 respectively. These estimates represent densities of whales at the surface only and were not corrected for submerged whales.

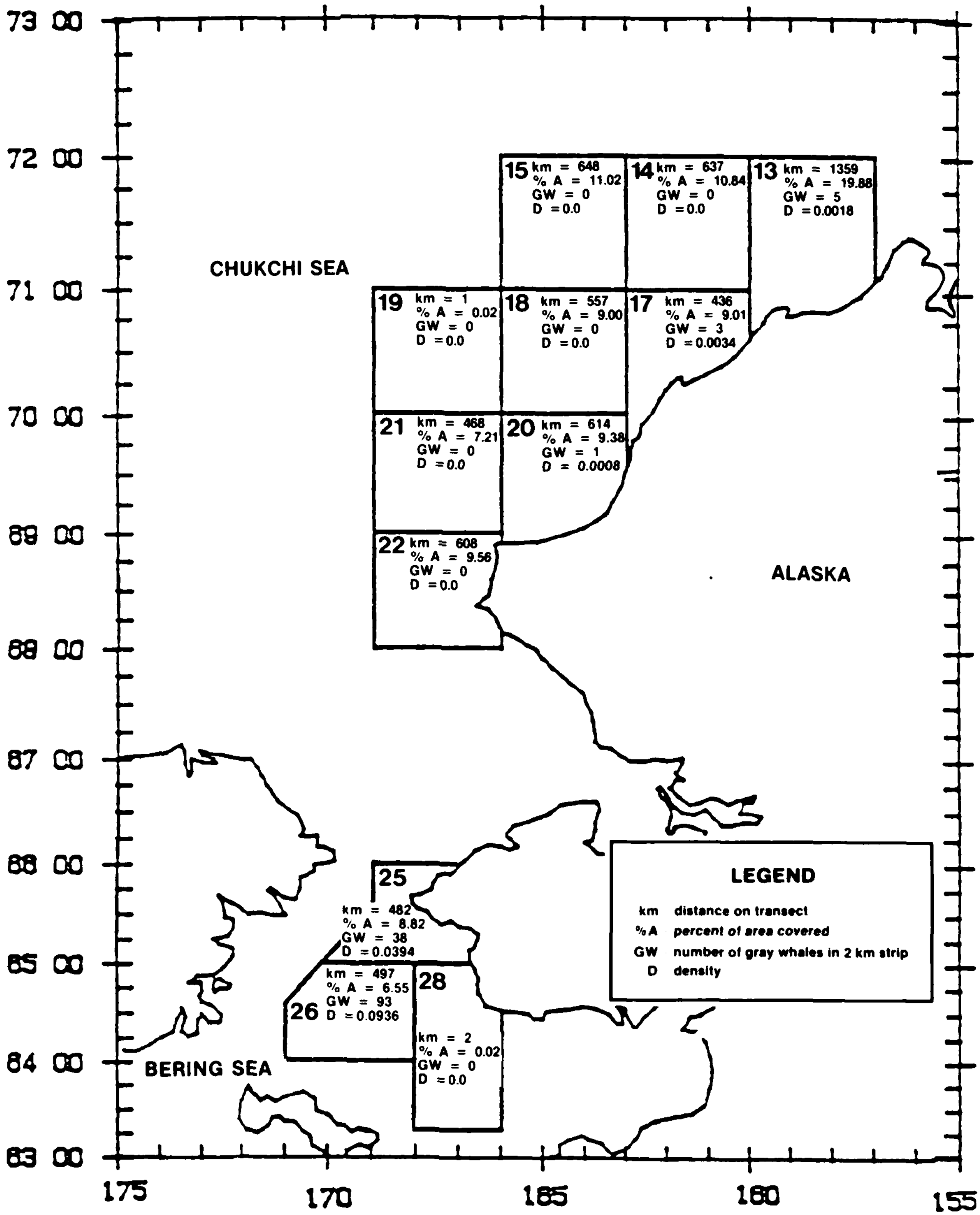


Figure 6. Gray whale density by block, summer 1985.

Although high gray whale relative abundance indices (WPUE) were calculated for blocks 22 and 24, density estimates could not be derived for these blocks because whale sightings were never made while surveying a random transect leg (see Figure 2).

Gray whale density estimates and relative abundance indices reflect the importance of the northern Bering Sea, and secondarily the coastal Chukchi Sea as summering habitat for gray whales. In 1985, the Chirikov Basin in the northern Bering Sea supported a summering aggregation of gray whales whose density was at least an order of magnitude greater than the densest area in the Chukchi Sea. Similar differences in abundance by sea have been noted for past years, although the magnitude of difference has varied annually (Appendix B: see Table B-2).

Habitat Relationships

Gray whales in the Bering Sea were seen approximately 0.5 to 140 km from shore in water 18 to 60 m deep ($\bar{x}$ = 45.1, s.d. = 7.56, n = 66). All gray whales (n = 477) seen in the Bering Sea were in open water. Grays seen in the Chukchi Sea were approximately 0.5 to 90 km from shore in water 5 to 42 m deep ($\bar{x}$ = 21.5, s.d. = 8.63, n = 73). Eighty-seven percent (n = 199) of gray whales seen in the Chukchi Sea were in open water, twelve percent (n = 27) were in 1 to 10 percent ice coverage, and less than 1 percent (n = 2) were seen in 20 to 30 percent ice coverage.

Behavior

Gray whales were usually seen either feeding (66 %, n = 466) or swimming (26 %, n =183; Table 6). Of the feeding whales seen, seventy-four percent (n = 346) were in the northern Bering Sea and 26 percent (n = 120) were in the Chukchi Sea. Feeding was inferred anytime a whale was seen with a mud plume. Mud plumes, billows of sediment brought to the surface by whales feeding on infaunal prey, are excellent sighting cues and as such may positively bias data toward "feeding" whales. Conversely, whales feeding on epibenthic prey may not create mud plumes and therefore some "feeding" whales may go unrecorded.

Three percent (n =22) of the grays seen were resting, sometimes in very shallow coastal water. Five percent (n = 34) of all gray whales seen were involved in cow-calf behaviors. The majority (n = 30) of these were seen in the Chukchi Sea south of Point Hope and along the northeastern coast between Icy Cape and Point Barrow.

Table 6. Observed gray whale behavior by sea, summer 1985.

	Bering Sea No.(%)	Chukchi Sea No.(%)	Total No.(%)
BEHAVIOR:			
Swim	118 (25)	64 (28)	182 (26)
Dive	0 (0)	1 (1)	1 (0)
Rest	9 (2)	13 (5)	22 (3)
Feed	346(72)	120(53)	466 (66)
Cow-Calf	4 (1)	30 (13)	34 (5)
TOTAL	477	228	705

Gray whale calves seen south of Point Hope (35%, n = 6) exhibited avoidance or "hiding" behavior on two days (Appendix A: Flights 2 and 3) similar to that seen in 1982 (Ljungblad et al., 1983). Each calf positioned itself under an adult whale, presumably the cow, so that only the calf's flukes could be seen. Occasionally a calf was seen momentarily resting close to an adult before submerging and "hiding" in what may have been an aircraft response.

Nine calves (53%) were seen swimming adjacent to an adult that was part of a larger feeding group both in the Bering (n = 2) and northeastern Chukchi Seas (n = 7). The remaining two calves (12%) were associated with swimming adults in the northeastern Chukchi Sea. One of these was swimming and breaching ahead of the adult (Appendix A: Flight 9).

Gray whales exhibited headings in all directions, with no significant clustering about any direction in either the northern Bering Sea (Rayleigh test, $z = 1.35$, $n = 15$, $p \leq 0.20$) nor the northeastern Chukchi Sea (Rayleigh test, $z = 1.87$, $n = 29$, $p \leq 0.10$).

Average group size for all gray whales was 3.38 (s.d. = 13.45, n = 103). Feeding gray whale groups were larger ($\bar{x} = 7.88$, s.d. = 15.75, n = 60) than groups of non-feeding whales ($\bar{x} = 4.56$, s.d. = 2.99, n = 43), but this difference was not significant ($t = 1.14$, df = 101, $p < 0.09$).

Recruitment

Seventeen gray whale calves were seen during the summer surveys resulting in a Gross Annual Recruitment Rate (GARR) of 17/705, or 2.4 percent. Fifteen of the calves were among the 228 whales in the northeastern Chukchi Sea (GARR = 6.58%), while only two calves were among the 477 gray whales in the northern Bering Sea (GARR = 0.42%). These differences in GARR by sea are similar to those reported for past years (Moore et al., 1986b), and may represent an example of partial segregation of cow-calf groups on the northern range. Annual estimates of GARR, and gray whale calf relative abundance for data collected in the northern Bering and eastern Chukchi Seas since 1980, further support the contention of partial cow-calf segregation on the northern range (see Table 23 and Table 24).

Other Species

Belukha Whale (Delphinapterus leucas)

Four sightings of 37 belukha whales were made in summer. One group of 30, consisting of primarily cows with calves, was seen near-shore in the northeastern Chukchi Sea on 20 July (Appendix A: Flight 4). All other sightings were of singles or small groups of adult whales. They consisted of one sighting of three belukas within 0.5 km of shore approximately 140 km southwest of Point Hope (Appendix A: Flight 3), a single whale seen about 40 km northwest of Point Barrow (Appendix A: Flight 9), and one sighting of three belukhas approximately 195 km north of Barter Island (Appendix A: Flight 13).

Pinnipeds

Thirty-seven bearded seals, 19 ringed seals, and 86 unidentified pinnipeds were seen in summer. Bearded seals and ringed seals were usually seen as singles in the Chukchi Sea. The largest loose aggregation of bearded (n = 19) and ringed (n = 13) seals was seen on 24 July (Appendix A: Flight 8) approximately 100 km north of Cape Lisburne. Walrus were sighted primarily along the ice edge and were usually swimming or in large (up to 600) groups resting on ice floes. Over 4000 walrus were seen northwest of Icy Cape on 23 July (Appendix A: Flight 7), and 1417 were counted on 24 July (Appendix A: Flight 8) in the same general area offshore between Cape Lisburne and Ice Cape where bearded and ringed seals were seen. Pinnipeds that reacted suddenly to the aircraft often could not be positively identified.

FALL (1 August to 23 October)

Survey Effort, Rationale, and Sighting Summary

Two hundred twelve and three-quarter hours of surveys were flown in the fall, with 93 percent (197.7 hrs) of this effort in the Beaufort Sea and 7 percent (15.1 hrs) in the Chukchi Sea (Table 7). Thirty-one percent (67.0 hrs) of the total flight time was flown in August (Figure 7A), 33 percent (69.8 hrs) in September (Figure 7B), and 36 percent (76.0 hrs) in October (Figure 7C; Table 8). Overall, survey effort was somewhat less extensive than that flown in 1982-84, but greater than that flown in 1979-81. Surveys were not flown on 12 days in August, 12 in September, and 6 in October due to poor weather or aircraft maintenance requirements (Table 8).

Surveys in the Beaufort Sea were scheduled to cover near-shore and offshore blocks, and to support other MMS-funded bowhead studies. Restrictive weather and lengthy transit time to some blocks altered planned coverage somewhat. In August and the first half of September, priority was given to blocks east of 150° W. In the latter part of September, first priority was given to all coastal blocks and to offshore blocks east of 150° W. In early October, surveys were directed toward near-shore blocks in the Beaufort Sea, and to near and offshore areas in the northern Chukchi Sea. Surveys during the latter part of October generally focused on the near-shore blocks of the eastern Alaskan Beaufort Sea to determine the status of the bowhead migration, as well as on the near-shore blocks of the western Beaufort Sea and the northern Chukchi Sea. Search surveys along the shifting ice edge or 20- to 40-m isobath were flown enroute to or from scheduled blocks.

Bowheads were seen east of 142°30'W and south of 70°35'N during August, east of 147°W near the continental shelf break and along the coastline in September, and west of 147°W along the shelf break and into the coastal Chukchi Sea in October. Although large aggregations (n = 50 to 600) of bowheads were reported between Kay Point (69°10'N, 138°20'W) and Shingle Point (68°55'N, 137°25'W), Canada, from late August through October (R. Davis, personal communication[1]), bowheads were not seen in substantial numbers in the Alaskan Beaufort Sea until late September-early October. This relatively late observed movement of the major proportion of whales into the Alaskan Beaufort Sea was similar to 1979 sighting data (Ljungblad et al., 1980).

Table 7. Summary of flight effort, fall 1985.

Flight	Date	Sea	Transect Length (km)	Search Length (km)	Connect Length (km)	Total Length (km)	Time on Transect (hr:min)	Total Time (hr:min)	WPUE (Whales/ hr)
14	2 Aug	Beaufort	675	191	90	956	2:26	3:28	0.00
15	6 Aug	Beaufort	111	728	14	853	0:23	3:05	0.00
16	7 Aug	Beaufort	571	499	88	1158	2:00	4:09	0.24
17	8 Aug	Beaufort	559	351	134	1044	2:02	3:48	1.05
18	9 Aug	Beaufort	224	505	56	785	0:50	2:52	0.00
19	11 Aug	Beaufort	289	473	84	846	1:07	3:14	0.93
20	12 Aug	Beaufort	62	543	0	605	0:14	2:11	0.00
21	14 Aug	Beaufort	202	416	122	740	0:46	2:50	0.00
22	15 Aug	Beaufort	586	425	70	1081	2:04	3:51	0.26
23	17 Aug	Beaufort	330	475	89	894	1:19	3:26	0.58
24	18 Aug	Beaufort	357	503	148	1008	1:21	3:50	0.00
25	19 Aug	Beaufort	112	156	85	353	0:28	1:25	0.00
26	21 Aug	Beaufort	588	321	141	1050	2:11	4:02	0.00
27	24 Aug	Beaufort	551	488	150	1189	2:08	4:42	0.00
28	25 Aug	Beaufort	351	475	102	928	1:21	3:30	0.00
29	27 Aug	Beaufort	452	399	184	1035	1:47	3:58	0.00
30	28 Aug	Beaufort	712	316	164	1192	2:37	4:25	0.00
31	29 Aug	Beaufort	854	540	238	1632	3:11	6:07	0.16
32	30 Aug	Beaufort	264	206	81	551	1:01	2:08	0.00
33	1 Sep	Beaufort	319	404	66	789	1:12	2:55	0.00
34	4 Sep	Beaufort	0	318	0	318	0:00	1:14	0.00
35	5 Sep	Beaufort	271	293	134	698	1:06	2:50	0.00
36	9 Sep	Beaufort	0	483	0	483	0:00	2:22	10.55
37	11 Sep	Beaufort	467	384	107	958	1:47	3:38	0.83
38	12 Sep	Beaufort	686	431	75	1192	2:36	4:36	0.00
39	13 Sep	Beaufort	823	90	124	1037	3:25	4:18	1.40
40	18 Sep	Beaufort	941	235	149	1325	3:35	5:06	0.00
41	19 Sep	Beaufort	769	458	67	1294	3:00	5:05	0.00
42	20 Sep	Beaufort	835	60	114	1009	3:18	4:10	0.00
43	22 Sep	Beaufort	469	789	113	1371	1:58	5:44	0.35

Table 7 (contd).

Flight	Date	Sea	Transect Length (km)	Search Length (km)	Connect Length (km)	Total Length (km)	Time on Transect (hr:min)	Total Time (hr:min)	WPUE (Whales/ hr)
44	23 Sep	Beaufort	528	305	141	974	2:07	3:54	0.00
45	24 Sep	Beaufort	537	530	94	1161	2:16	4:57	0.00
46	25 Sep	Beaufort	593	518	131	1242	2:27	5:37	1.25
47	26 Sep	Beaufort	553	377	111	1041	2:20	4:24	0.91
48	27 Sep	Beaufort	391	514	55	960	1:33	4:17	4.44
49	29 Sep	Beaufort	442	472	96	1010	1:47	4:00	0.25
50	30 Sep	Beaufort	34	105	16	155	0:10	0:39	0.00
51	1 Oct	Beaufort	735	329	133	1197	3:13	5:16	1.71
52	3 Oct	Beaufort	708	162	91	961	2:53	4:07	0.00
53	5 Oct	Beaufort	834	22	144	1000	3:24	4:32	1.10
54	6 Oct	Beaufort	555	426	112	1093	2:10	4:58	5.23
55	7 Oct	Beaufort	895	451	86	1432	3:28	5:30	0.00
56	10 Oct	Chukchi	115	611	47	773	0:31	3:14	0.00
57	11 Oct	Beaufort	545	364	84	993	2:19	4:12	0.48
58	12 Oct	Chukchi	880	463	169	1512	3:30	6:10	0.32
		Beaufort	0	17	0	17	0:00	0:05	12.50
59	13 Oct	Beaufort	309	553	121	983	1:18	4:21	2.99
60	14 Oct	Beaufort	480	330	148	958	1:59	3:52	0.00
61	15 Oct	Chukchi	0	544	0	544	0:00	2:06	0.48
		Beaufort	0	14	0	14	0:00	0:03	0.00
62	16 Oct	Beaufort	543	151	127	821	2:28	3:41	0.27
63	17 Oct	Beaufort	537	348	125	1010	2:13	4:13	0.00
64	19 Oct	Beaufort	671	167	141	979	2:54	4:23	0.00
65	20 Oct	Beaufort	992	740	209	1941	4:02	7:32	0.00
66	21 Oct	Beaufort	592	107	119	818	2:17	3:22	0.00
67	23 Oct	Chukchi	701	105	55	861	2:56	4:37	0.00
		Beaufort	145	4	33	182	0:35	0:46	0.00
Beaufort Sea Total			25049	18961	5306	49316	99:06	197:43	0.69
Chukchi Sea Total			1696	1723	271	3690	6:57	15:07	0.20
TOTAL			26745	20684	5577	53006	106:03	212:50	0.65

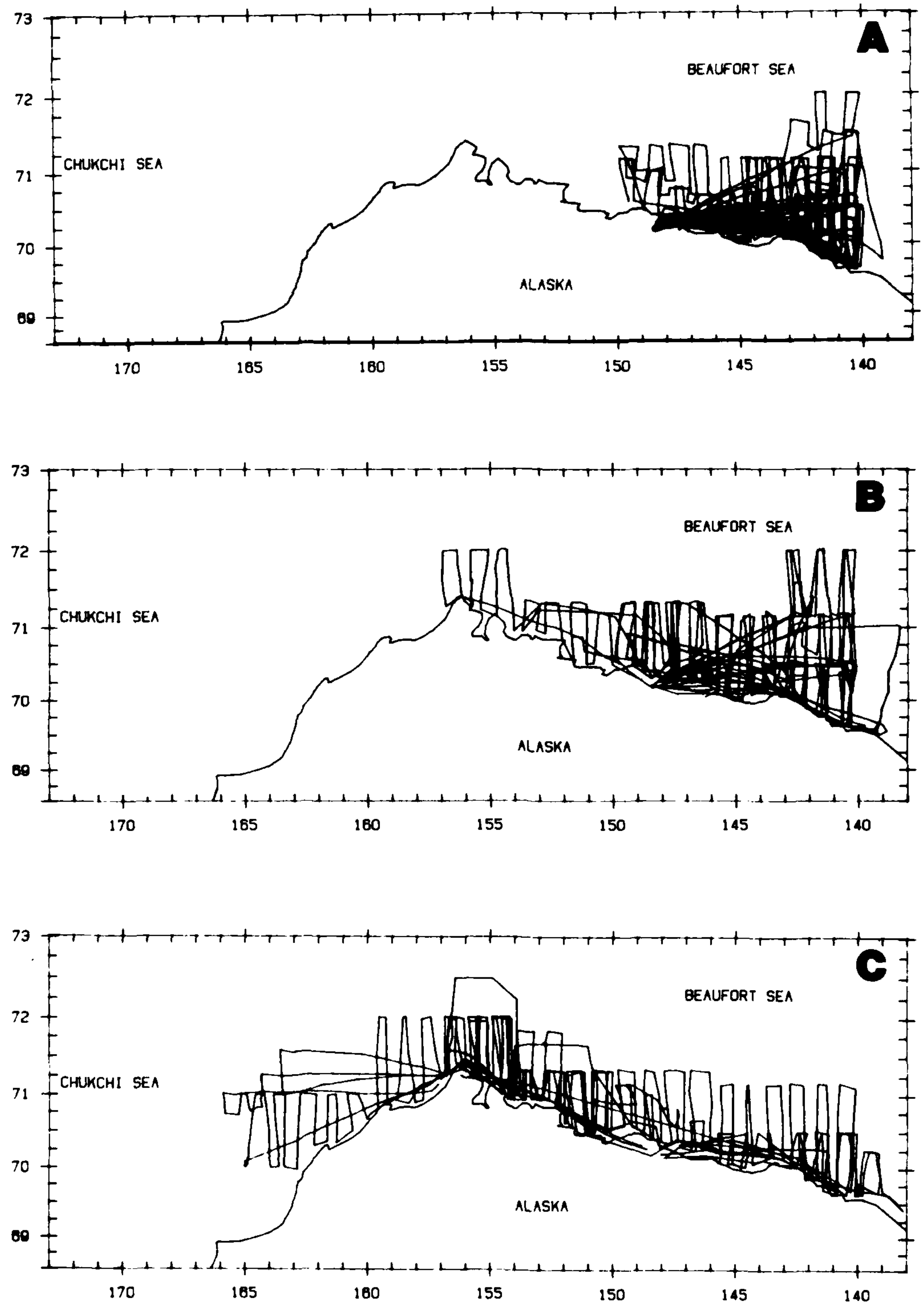


Figure 7. Composite flight tracks, fall 1985: 19 flights in August (A); 18 flights in September (B); and 17 flights in October (C).

Table 8. Monthly summary of flight effort, fall 1985.

	AUG	SEP	OCT	TOTAL
FLIGHT EFFORT				
Total Transect Length (km)	7850	8658	10237	26745
Total Connect Length (km)	2040	1593	1944	5577
Total Search Length (km)	8010	6766	5908	20684
Total Time on Transect (hr:min)	29:16	34:37	42:10	106:03
Total Flight Time (hr:min)	67:01	69:46	76:03	212:50
No. Flight (days)	19	18	17	54
Unacceptable Weather (days)	12	11	5	28
Aircraft Maintenance (days)	0	1	1	2

The secondary aircraft (N545N) flew 42.8 hours of surveys in the eastern Alaskan Beaufort Sea from 9 to 27 September to monitor the status of the bowhead migration (Appendix C: Table C-1, Figure C-1). Surveys were conducted to coastal areas near the U.S.-Canadian border where aggregations of 10 to 25 bowheads were seen over a two week period (Appendix C: Flights C-2 to C-9).

Survey Conditions Summary

Survey conditions in early August were generally poor. During the first half of the month, low ceilings and dense fog prevented flying on six out of 15 days and caused transects to be truncated or aborted on five occasions. The weather improved slightly during the latter half of August, allowing more transect surveys to be completed. Heavy fog extending from Barrow to Canada precluded flying on six of 16 days, and low altitude search surveys were flown on four days.

Survey conditions in early September were poor. Persistent low fog prevented flying on seven days, and caused transects to be truncated or aborted on four of the seven surveys completed. Survey conditions improved during the latter half of September, although low overcast, fog and/or high winds precluded flying on four days.

Survey conditions in October were generally good in areas with heavy ice, with the exception of persistent high winds which precluded flying on 5 days. In the ice-free areas of the Chukchi Sea, survey conditions were usually poor due to reduced visibility, fog, and high sea states (up to Beaufort 7).

Ice coverage in the Beaufort Sea in August remained heavy. In early August, there was 5 to 10 percent ice coverage in Camden Bay and waters near Barter Island (Figure 8A). There was a narrow channel (approximately 25 km) of nearly ice-free (0-5%) water between Deadhorse and Barter Island that broadened and extended from shore north to 70°40'N east of Barter Island. Ice coverage was greater than 90 percent throughout the rest of the eastern Alaskan Beaufort Sea. By mid-August, the heavy ice edge had moved farther offshore east of Barter Island (Figure 8B). Nearly ice-free (0-5%) water extended from shore to 70°20'N at 141°W, broadening to 71°N at 139°W and east. Ice coverage varied from 10 to 50 percent due north of Deadhorse, with the heavy ice (95-99%) edge about 55 km offshore.

The heavy ice edge continued to move offshore in the northeastern Beaufort Sea during early September (Figure 9A). Except for localized near-shore bands of 5 to 20 percent and 1 to 10 percent ice north of Prudhoe Bay and east of Barter Island, the eastern Beaufort Sea was relatively ice-free to 70°50'N at 150°W extending northeast to nearly 72°N at 140°W by mid-month. A four-day storm with strong winds ($\geq$40 knots) changed Beaufort Sea ice conditions dramatically in mid-September (Figure 9B). Heavy ice was blown near shore, and ice conditions were generally heavy (80 to 99%) throughout the northeastern Beaufort Sea, with localized areas of moderate to heavy coverage (30 to 60%, 50 to 80%) and light to moderate conditions (5 to 50%) encountered near the U.S.-Canadian border. By the latter part of September, the heavy ice edge had again retreated from shore (Figure 9C). Although a region of moderate to heavy ice (40 to 90%) persisted north of Barter Island and light to moderate coverage (5 to 40%) was found east of there, the remainder of the Beaufort Sea was nearly ice-free (< 10%) to about 71° 20'N.

As temperatures dropped in early October (5° to 20°F), new ice began to form rapidly in the shallow areas of the Alaskan Beaufort Sea. Ice coverage was light to moderate (20 to 30%) east of Deadhorse extending north to 70°30'N, where it increased to 50 to 99 percent (Figure 10A). There was eighty percent new ice coverage near-shore north of Deadhorse and west to Harrison Bay, with lighter ice

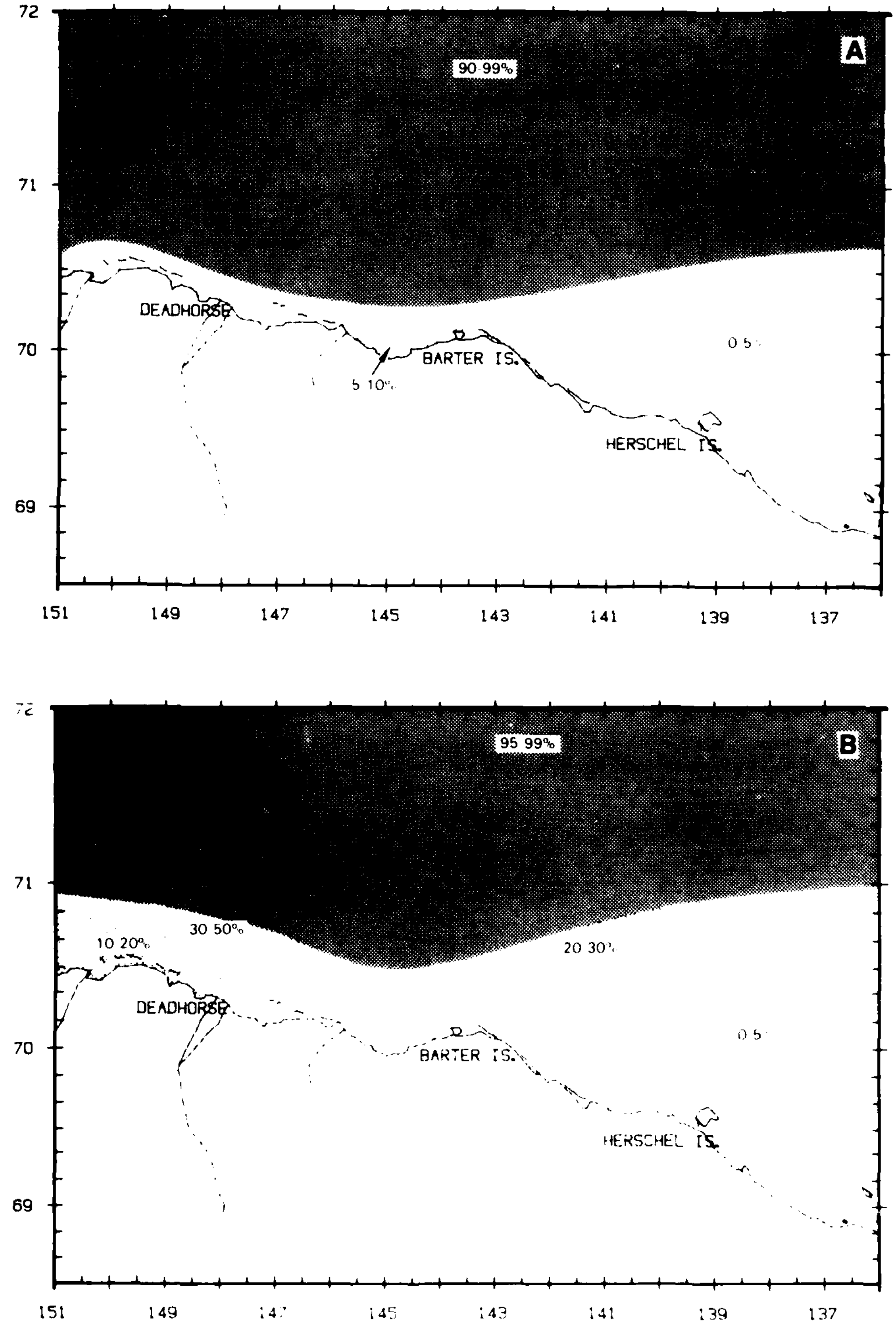


Figure 8. Schematic representation of ice conditions in the Beaufort Sea, 1-15 August (A); and 16-31 August (B).

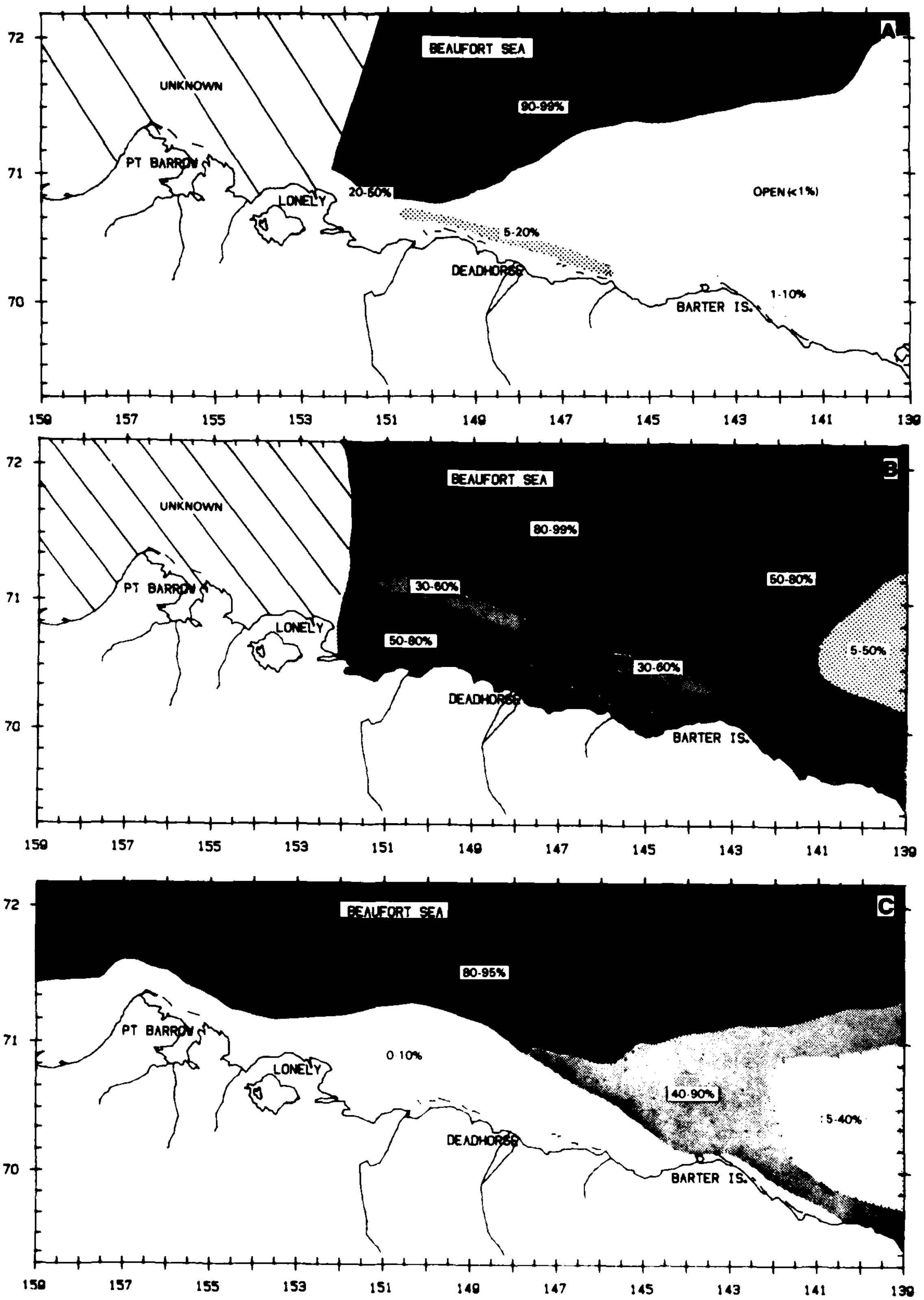
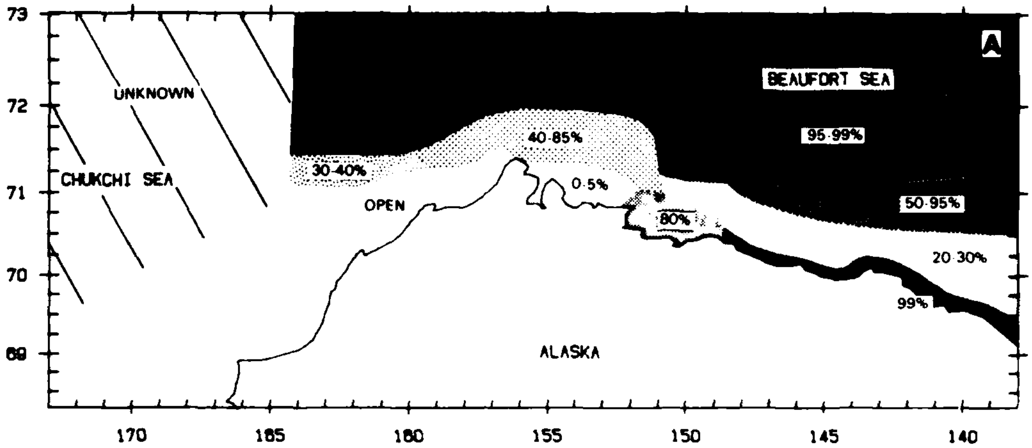


Figure 9. Schematic representation of ice conditions in the Beaufort Sea, 1-15 September (A); 16-20 September (B); and 21-30 September (C).



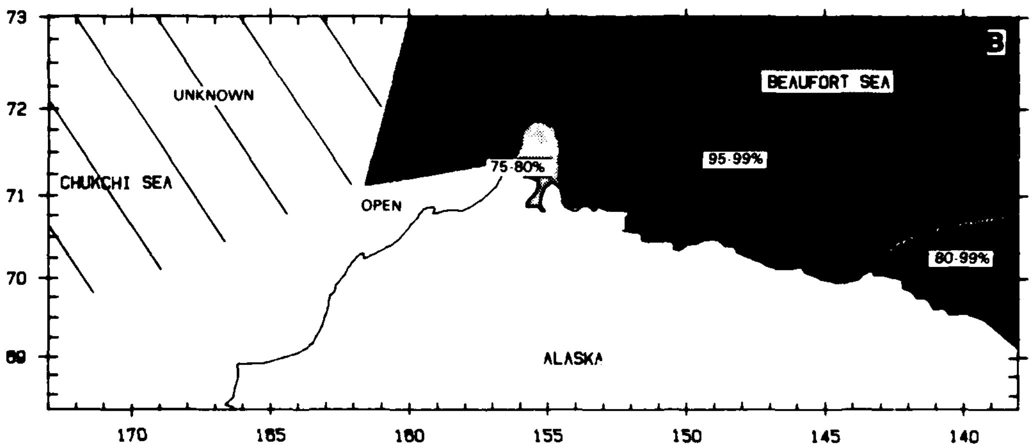


Figure 10. Schematic representation of ice conditions in the Chukchi and Beaufort Seas, 1-15 October (A); and 16-23 October (B).

coverage (0-5%) near-shore west of 152°W. North of Smith Bay (154°W) and extending west of Barrow, 40 to 85 percent ice existed north of 71°N. In mid-October, persistent low temperatures (0° to 5°F) caused most of the Alaskan Beaufort Sea to freeze almost entirely (95 to 99%), with the exception of a near-shore area east of 143°W, where coverage was 80 to 99 percent, and a small area northeast of Barrow where numerous cracks and leads persisted resulting in 75 to 80 percent coverage (Figure 10B). By 21 October, the Alaskan Beaufort Sea was determined to have 99 percent coverage nearly everywhere.

Much of the Chukchi Sea remained ice-free through 23 October. In early October, heavy ice (95 to 99%) existed north of 71°30'N and a 25-km strip of moderate ice coverage (30 to 40%) was south of this (Figure 10A). By mid-October, areas previously covered with 40 percent ice were 95 percent covered (Figure 10B). The near-shore areas remained open through 23 October, although heavy ice had formed directly off Barrow.

Bowhead Whale (*Balaena mysticetus*)

Distribution, Relative Abundance, and Density

Seventy-seven sightings of 139 bowheads were made during the fall season (Table 9; Figure 11). Twelve bowheads were seen in August near the easternmost Outer Continental Shelf (OCS) oil and gas lease areas between 140°W and 142°W and offshore to 70°31'N (Figure 11A). This August distribution was similar to that of 1984 but dissimilar to that of 1982 and 1983 when whales were generally found farther offshore and farther west (to 146°30'W) along or outside the shelf break (Ljungblad et al., 1985).

Sixty-seven bowheads were seen in September (Figure 11B), fewer whales for this month than during all previous years except 1980 (Ljungblad, 1981). Whales were distributed in three discrete groupings: along the coast between 139°W and 141°W (n = 31); approximately 35 km north of Barter Island between 143°W and 144°W (n = 26); and about 40 km north northwest of Flaxman Island between 145°30'W and 147°W (n = 10). The distribution of bowheads in September overlapped the eastern OCS oil and gas lease areas somewhat and was similar to, but not comprehensive of, that seen in prior years (Ljungblad et al., 1985).

Fifty-seven bowheads were seen in the Beaufort Sea in October (Figure 11C), more whales for this month than in 1980-83, but less than in 1979 and 1984 (Ljungblad et al., 1985). All were seen eight to 110 km offshore east of 147°20'W, and some were within the northwestern boundaries of OCS lease areas. Two relatively large groupings of bowheads were seen in early October; one consisting of eight whales 87 km northeast of Lonely, and one group of 20 whales north of Harrison Bay (Appendix A: Flights 51 and 54). In mid-October, two groups (n = 6 and 7) of bowheads were seen 45-55 km north of Prudhoe Bay (Appendix A: Flight 59). Three bowheads were seen in the Chukchi Sea in October, between 2 and 44 km offshore (Appendix A: Flight 58 and 61). As in September, the distribution of bowheads in October was similar to, but not comprehensive of, that seen in prior years (Ljungblad et al., 1985).

Table 9. Summary of sightings (number of sightings/number of animals), fall 1985.

Flight	Date	Bowhead	Belukha	Bearded Seal	Ringed Seal	Unidentified Pinniped	Polar Bear
14	2 Aug	0	1/1	0	0	0	0
15	6 Aug	0	0	0	0	0	0
16	7 Aug	1/1	0	0	0	2/2	0
17	8 Aug	4/4	3/9	1/1	0	1/1	0
18	9 Aug	0	2/2	1/1	0	0	0
19	11 Aug	2/3	5/25	1/1	0	2/2	0
20	12 Aug	0	1/2	0	0	0	0
21	14 Aug	0	0	0	0	0	0
22	15 Aug	1/1	6/9	0	0	1/1	0
23	17 Aug	2/2	1/2	0	0	0	0
24	18 Aug	0	1/11	1/1	0	5/8	0
25	19 Aug	0	0	0	0	0	0
26	21 Aug	0	0	0	0	0	0
27	24 Aug	0	0	0	0	0	0
28	25 Aug	0	1/1	0	0	0	0
29	27 Aug	0	0	0	0	5/5	0
30	28 Aug	0	11/36	0	0	2/3	0
31	29 Aug	1/1	12/24	1/1	0	0	0
32	30 Aug	0	0	0	0	0	0
33	1 Sep	0	3/4	0	0	0	0
34	4 Sep	0	0	0	0	0	0
35	5 Sep	0	1/1	0	0	0	0
36	9 Sep	9/25	0	0	0	0	0
37	11 Sep	1/3	3/5	0	0	3/4	0
38	12 Sep	0	1/1	1/2	0	1/2	0
39	13 Sep	3/6	1/1	3/4	0	1/1	0
40	18 Sep	0	3/6	1/1	0	0	0
41	19 Sep	0	2/3	2/3	0	1/1	0
42	20 Sep	0	2/11	0	0	0	0

Table 9 (contd).

Flight	Date	Bowhead	Belukha	Bearded Seal	Ringed Seal	Unidentified Pinniped	Polar Bear
43	22 Sep	2/2	7/25	0	0	1/1	0
44	23 Sep	0	0	0	0	3/3	0
45	24 Sep	0	10/120	1/1	1/1	2/2	0
46	25 Sep	5/7	2/6	0	0	3/3	1/1
47	26 Sep	3/4	1/2	0	0	5/5	0
48	27 Sep	7/19	4/25	0	0	1/1	0
49	29 Sep	1/1	1/4	1/1	0	2/2	0
50	30 Sep	0	0	0	0	0	0
51	1 Oct	7/9	12/49	0	0	0	0
52	3 Oct	0	0	0	0	0	0
53	5 Oct	4/5	0	0	0	0	0
54	6 Oct	8/26	3/15	0	0	1/1	0
55	7 Oct	0	2/2	0	0	1/1	0
56	10 Oct	0	0	1/1	0	0	2/2
57	11 Oct	2/2	4/12	1/1	0	1/1	0
58	12 Oct	3/3	1/10	0	0	0	0
59	13 Oct	9/13	1/1	0	0	0	0
60	14 Oct	0	0	0	0	0	0
61	15 Oct	1/1	0	0	0	0	0
62	16 Oct	1/1	7/9	0	0	0	1/3
63	17 Oct	0	0	0	0	0	0
64	19 Oct	0	0	0	0	0	0
65	20 Oct	0	1/5	0	0	0	0
66	21 Oct	0	0	0	0	0	0
67	23 Oct	0	0	0	0	0	0
August		11/12	44/122	5/5	0/0	18/22	0/0
September		31/67	41/214	9/12	1/1	23/25	1/1
October		35/60	31/103	2/2	0/0	3/3	3/5
Total		77/139	116/439	16/19	1/1	44/50	4/6

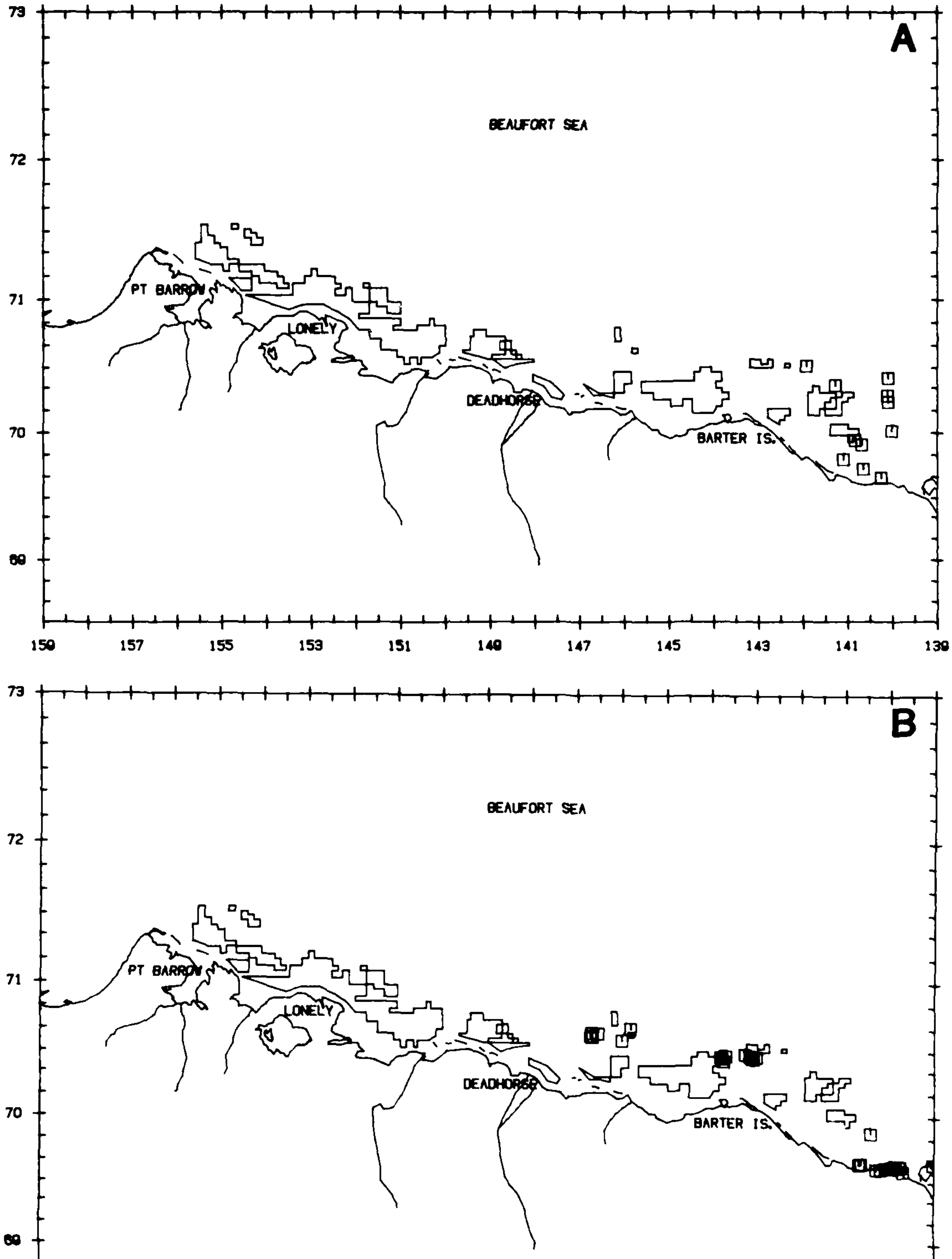


Figure 11. Distribution of 77 sightings of 139 bowheads, fall 1985: 11 sightings of 12 bowheads, August (A); 31 sightings of 67 bowheads, September (B); (contd next page)

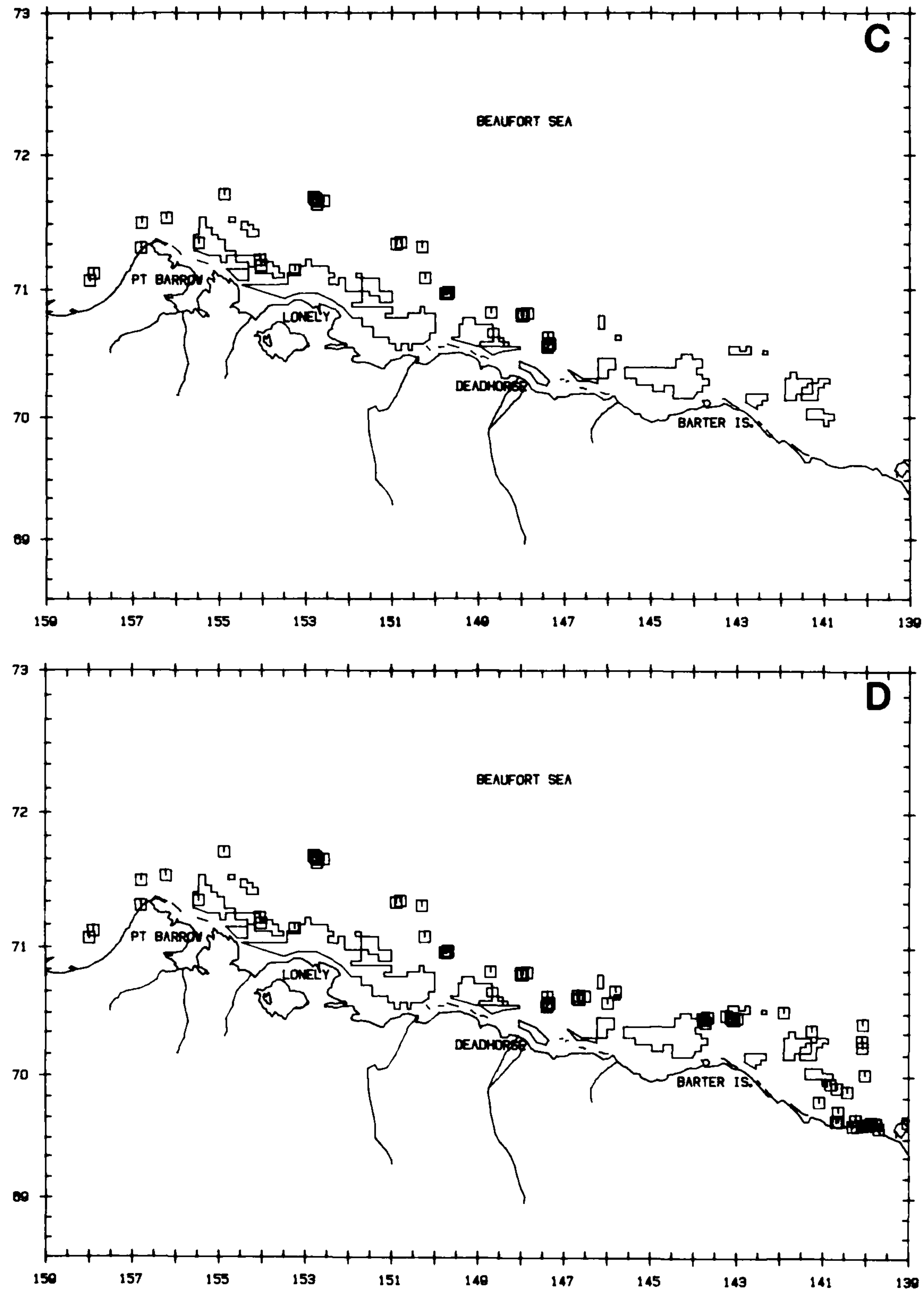


Figure 11 (contd). 35 sightings of 60 bowheads, October (C); all sightings (D). Outlined areas depict OCS oil and gas lease areas within the Beaufort Sea Planning Area of the Alaskan Beaufort Sea.

Bowhead relative abundance within the survey blocks (WPUE) ranged from 8.46 (block 11) to 0.06 (block 7; Table 10). Relative abundance was highest in block 5 in August (WPUE = 0.63), block 4 in September (WPUE = 2.21) and block 11 in October (WPUE = 9.00), reflecting a westward shift in flight effort and sightings with time. These relative abundance indices were generally similar to prior years (see Table 26).

Bowhead density estimates calculated for the survey blocks generally reflected trends evident in the analysis of relative abundance (Figure 12). Density was highest in block 5 in August (0.0011 whales/km^2) and September (0.0007 whales/km^2), and block 11 in October (0.0045 whales/km^2). Total density estimates for the season were 0.0044 whales/km^2 in block 11, 0.0008 whales/km^2 in block 12, 0.0006 whales/km^2 in block 5, 0.0004 whales/km^2 in block 3 and 0.0003 whales/km^2 in block 1. Bowhead density could not be calculated for survey blocks in the Chukchi Sea because whales were never seen there while flying a random transect survey line. The calculation of bowhead density estimates for bathymetrically derived subregions in the Alaskan Beaufort Sea are presented in Appendix B.

Migration Route, Timing, and Habitat Relationships

The observed bowhead migration route across the Alaskan Beaufort Sea was centered roughly along the continental shelf break (Figure 11D) as in past years (Ljungblad et al., 1985). Bowheads were seen in the Alaskan Beaufort Sea as early as 7 August (Appendix A: Flight 16) from the primary aircraft (N780), and by 11 September (Appendix C: Flight C-2) from the secondary aircraft (N545N); but, except for one whale swimming slowly west near Demarcation Bay on 17 August (Appendix A: Flight 23), all bowheads seen between 7 August and 13 September were resting, displaying, feeding, or swimming slowly in other than a westerly direction and did not appear to be migrating. From 14 to 17 September, neither aircraft flew surveys due to a severe storm that hit Alaska's North Slope in mid-September (see Survey Conditions Summary, pp. 25-28). This hiatus in survey effort made a precise onset of the bowhead migration somewhat difficult to determine because whales seen prior to 14 September may have migrated west during the storm. One bowhead was seen just north of Point Barrow on 18 September (K. Frost, personal communication[2]) indicating that some whales had moved across the Alaskan Beaufort Sea by that time. However, there were no bowhead sightings from the primary aircraft (N780) on surveys conducted from 18

Table 10. Monthly and seasonal relative abundance of bowhead whales (WPUE) by survey block, fall 1985.

Block No.	August				September				October				Total			
	Flts	Hrs	BH	WPUE	Flts	Hrs	BH	WPUE	Flts	Hrs	BH	WPUE	Flts	Hrs	BH	WPUE
1	19	10.67	0	-	17	13.04	7	0.54	8	7.97	18	2.26	44	31.68	25	0.79
2	3	1.67	0	-	3	4.16	0	-	1	1.75	0	-	7	7.58	0	-
3	0	0.00	0	-	3	4.90	0	-	7	12.38	5	0.40	10	17.28	5	0.29
4	18	16.75	0	-	11	10.39	23	2.21	6	6.22	0	-	35	33.36	23	0.69
5	14	17.52	11	0.63	9	10.89	19	1.74	4	9.16	0	-	27	37.57	30	0.80
6	12	7.31	0	-	8	7.78	3	0.39	3	2.09	0	-	23	17.18	3	0.17
7	11	8.70	1	0.11	7	7.08	0	-	4	2.08	0	-	22	17.86	1	0.06
8	5	3.01	0	-	6	5.33	0	-	1	0.06	0	-	12	8.40	0	-
9	2	0.32	0	-	3	0.36	0	-	0	0.00	0	-	5	0.68	0	-
10	1	0.16	0	-	3	0.18	0	-	1	0.25	0	-	5	0.59	0	-
11	0	0.00	0	-	1	0.19	0	-	5	3.00	27	9.00	6	3.19	27	8.46
12	0	0.00	0	-	1	3.08	0	-	12	13.25	7	0.53	13	16.33	7	0.43
13	0	0.00	0	-	0	0.00	0	-	4	6.40	2	0.31	4	6.40	2	0.31
14	0	0.00	0	-	0	0.00	0	-	3	2.09	1	0.48	3	2.09	1	0.48
15	0	0.00	0	-	0	0.00	0	-	3	1.00	0	-	3	1.00	0	-
17	0	0.00	0	-	0	0.00	0	-	1	2.69	0	-	1	2.69	0	-
18	0	0.00	0	-	0	0.00	0	-	2	2.90	0	-	2	2.90	0	-
Block Total	85	66.11	12	0.18	72	67.38	52	0.77	65	73.29	60	0.82	222	206.78	124	0.60
Total Canada	3	0.91	0	-	3	2.30	15	6.52	2	1.96	0	-	8	5.17	15	2.90
Total Unblocked	0	0.00	0	-	2	0.09	0	-	2	0.78	0	-	4	0.87	0	-
Grand Total	88	67.02	12	0.18	77	69.77	67	0.96	69	76.03	60	0.79	234	212.82	139	0.65

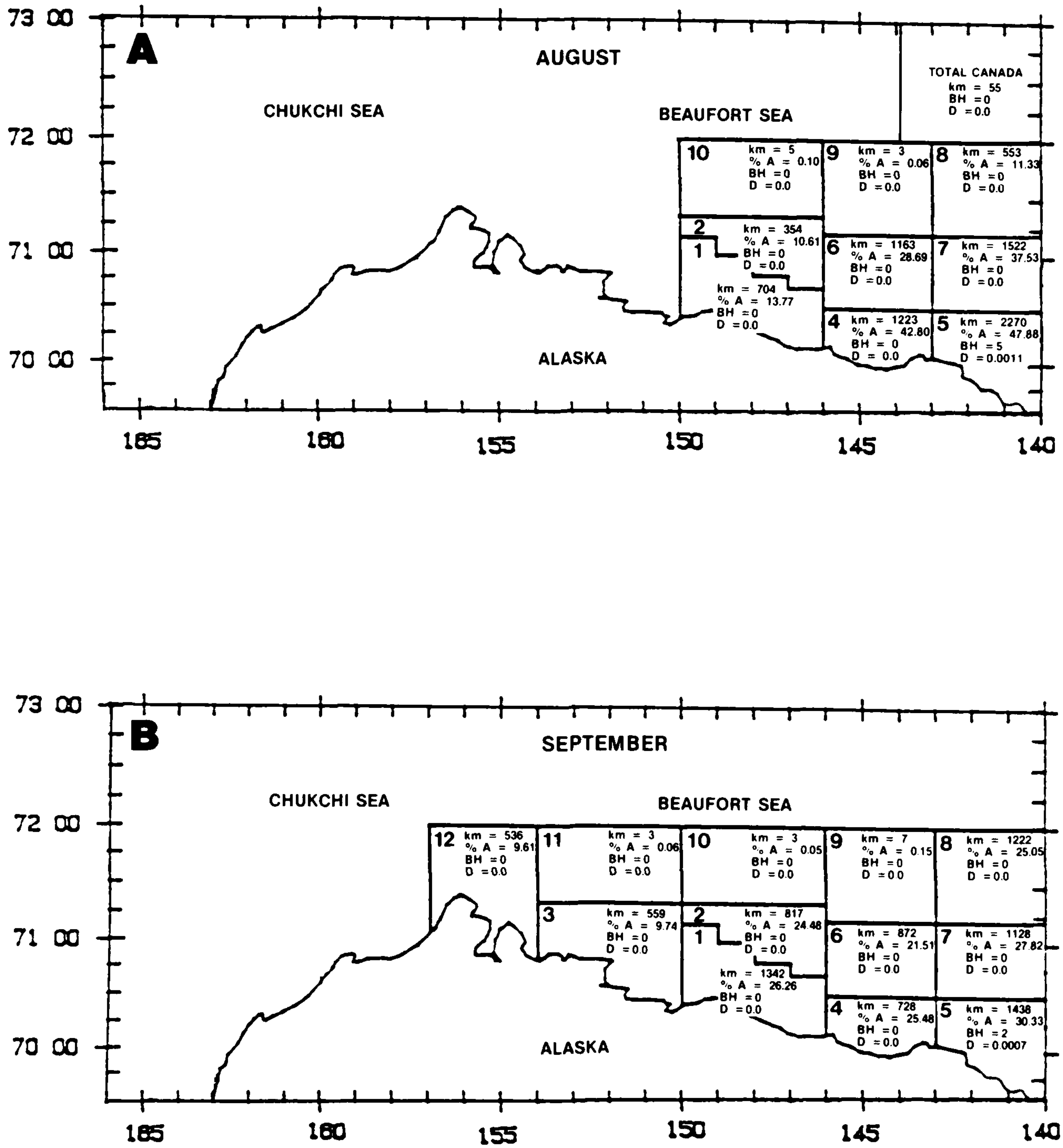
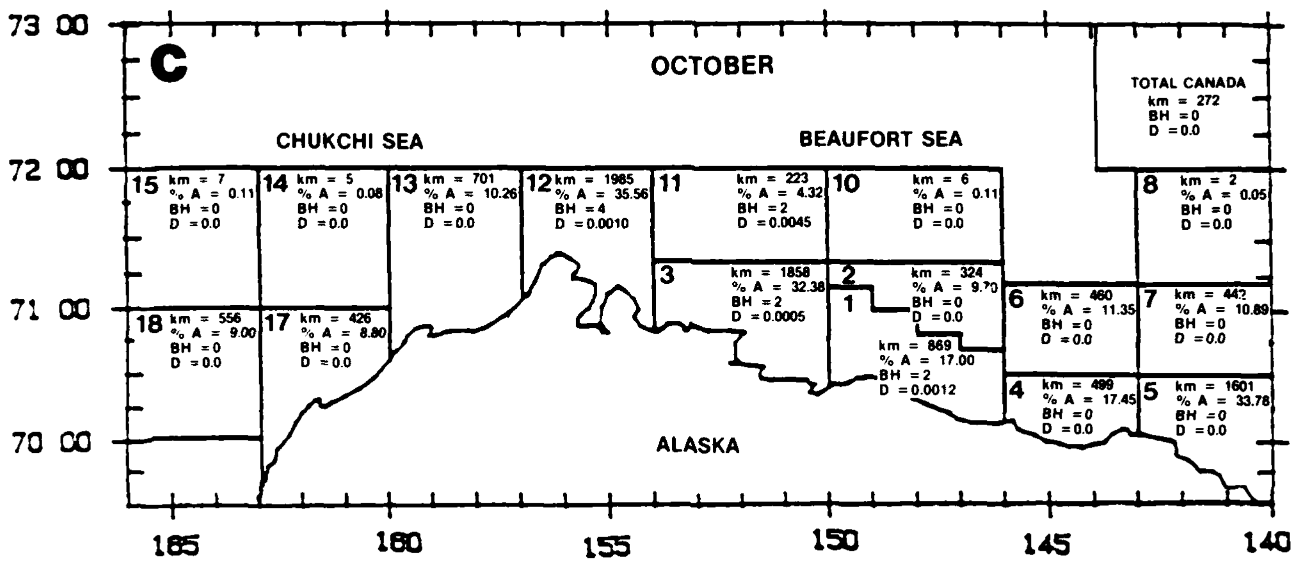


Figure 12. Bowhead whale density by block, fall 1985: August (A); September (B). (contd next page)



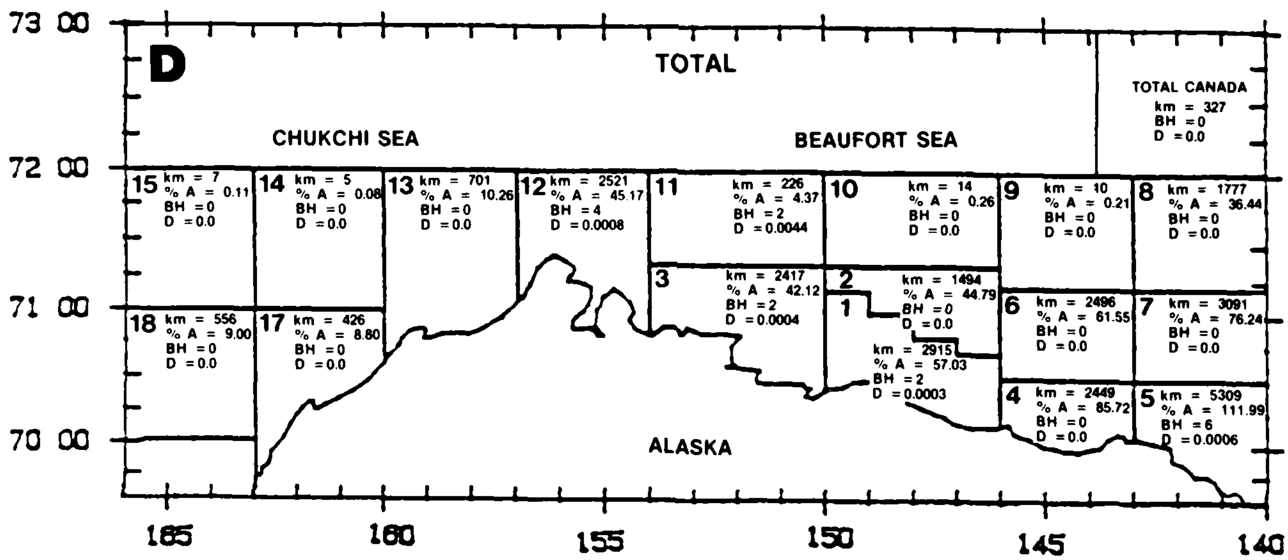


Figure 12 (contd). Bowhead whale density by block, fall 1985: October (C); all sightings (D).

to 20 September (Appendix A: Flights 40 to 42), and only one whale was seen from the secondary aircraft on 19 September (Appendix C: Flight C-6) indicating that whales were not migrating through the Alaskan Beaufort Sea east of 150°W in the days immediately following the storm.

The observed migration period began on 22 September, when two bowheads were seen from N780 (Appendix A: Flight 43) swimming in a northwesterly direction east of Demarcation Bay, and one whale was seen from N545N (Appendix C: Flight C-7) swimming west approximately 63 km east of Barter Island. The last bowhead seen in the Alaskan Beaufort Sea by this project was at 71° 30.7'N, 156° 47.0'W on 16 October (Appendix A: Flight 62). A few bowheads (n = 7) were seen after 16 October in the Alaskan and Canadian Beaufort Seas by researchers on other aircraft surveying near-shore areas (J. Richardson, personal communication[3]). No bowheads were seen on transect surveys in Canadian waters and in blocks 1, 3, 4,and 5 on 19 and 20 October, nor on surveys of blocks 3, 12,and 13 on 21 and 23 October. The end of the migration period was determined as 20 October after researchers on N780 and two other aircraft (J. Richardson, personal communication[3]) surveyed areas in the western Canadian and Alaskan Beaufort Seas between 139°W and 152°W on two consecutive days and saw no bowheads, indicating that the majority of the migration was probably past.

There were three single-day WPUE peaks in the Alaskan Beaufort Sea during the 22 September to 20 October migration period (Figure 13). The first WPUE peak (4.80) resulted from the sighting of 16 to 19 bowheads, including three calves, that were resting, milling,and swimming slowly approximately 40 km north northeast of Barter Island on 27 September (Appendix A: Flight 48; Appendix C: Flight C-11). A second WPUE peak (5.23) occurred on 6 October (Appendix A: Flight 54) when 26 bowheads, including one group of 18 whales with three calves, were seen between Deadhorse and Smith Bay. The third relatively high WPUE (2.99) was calculated for 13 October when 13 bowheads were seen approximately 55 km north of Deadhorse.

a. Bowhead Sighting Summary From Ten Aerial Survey Crews

Ten aircraft and crews dedicated to surveying for bowhead whales flew over the Chukchi and Alaskan and Canadian Beaufort Seas in August, September, and October 1985 (Table 11). The only aircraft to fly random line transects covering the entire Alaskan Beaufort Sea (140°W to 157°W) was the primary aircraft (N780) from this project. All other aircraft flew either systematic transect surveys or

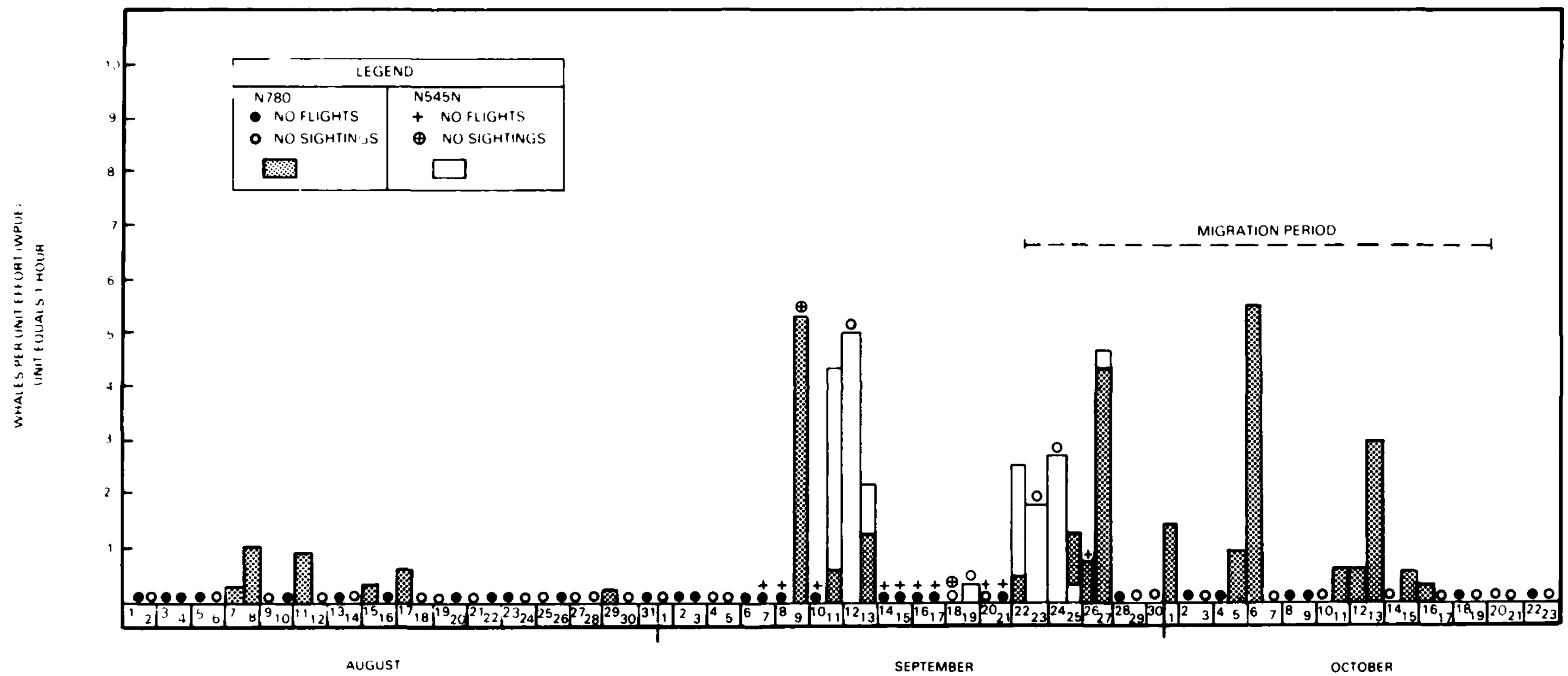


Figure 13. Bowhead whales per unit effort (WPUE) in the Alaskan Beaufort Sea by date, fall 1985.

Table 11. Bimonthly summary of bowhead sightings (number of sightings/number of whales) by ten aircraft and crews surveying the Alaskan Beaufort Sea (ABS), the Canadian Beaufort Sea (CBS) and the Chukchi Sea (CS), August-October 1985

Aircraft	August		1-15 September		16-30 September			October			Total			Total
	ABS	CBS	ABS	CBS	CS	ABS	CBS	CS	ABS	CBS	CS	ABS	CBS	
N780	11/12	0/0	3/6	10/28	0/0	15/30	3/3	3/3	32/57	0/0	3/3	61/105	13/31	77/139
N545N	-	-	5/53	0/0	-	16/53	0/0	-	-	-	-	19/106	0/0	19/106
*LGL-In/Gov (2 aircraft)	0/0	87/1290	0/0	22/1202	-	-	-	-	-	-	-	0/0	109/2492	109/2492
ESL	3/4	24/76	4/18	32/55	-	-	0/0	-	-	-	-	7/22	56/131	63/153
LGL-Union	-	-	6/10	-	-	13/13	-	-	10/13	-	-	29/36	-	29/36
LGL-Shell	-	-	0/0	-	-	5/5	-	-	9/18	0/0	-	14/23	0/0	14/23
LGL-Feeding Study	-	-	8/102	0/0	-	25/92	2/5	-	-	-	-	33/194	2/5	35/199
LGL-Shell (Inuvik)	-	-	-	-	-	-	-	-	1/2	26/119	-	1/2	26/119	27/121
USFWS (Barrow)	-	-	-	-	4/5	5/8	-	4/6	0/0	-	8/11	5/8	-	13/19
Total	14/16	111/1366	24/189	64/1285	4/5	79/201	5/8	7/9	52/90	26/119	11/14	169/496	206/2778	386/3288

- = no effort reported

*LGL-In/Gov includes the following industry and government agencies: Amerada Hess Corporation, Amoco Production Company, BP Alaska Exploration, Chevron USA, Exxon USA, Shell Western E&P, Standard Alaska Production Company, Tenneco, Texaco, Unocal, Canadian Department of Fisheries and Oceans, Canadian Department of Indian and Northern Affairs, National Marine Fisheries Service, North Slope Borough, U.S. Marine Mammal Commission. Number of whales is estimated.

search surveys north to 72°N and between 144°W and 117°W (N545N, Appendix C; LGL-Feeding Study, Richardson et al., 1985c; LGL-Shell (Inuvik), J. Richardson, personal communication[3]; ESL, Environmental Sciences Limited, L. Harwood, personal communication[4]; LGL-In/Gov, G. Miller, personal communication[5]), or fixed-grid systematic surveys near drill sites, one of which extended north to 70°45'N between 144°20'W and 146°50'W (LGL-Union; J. Richardson, personal communication[3]) and the other which extended north to 71°N between 147°40'W and 149°30'W (LGL-Shell; S. Johnson, personal communication[6]). One aircraft (USFWS; K. Frost, personal communication[2]) conducting line transect surveys for walrus in the northeastern Chukchi Sea provided incidental bowhead sighting data for that area. Although flight effort and survey rationale varied with each aircraft, an analysis of sighting data from all aircraft was undertaken in order to present the most comprehensive picture of the fall 1985 bowhead migration during the August- October time period.

In August, one aircraft (N780) was dedicated to surveying for bowheads in the Alaskan Beaufort Sea (west of 140°W), with three additional aircraft (LGL-In/Gov, two aircraft, and ESL) surveying in the Canadian Beaufort. Numerous bowheads (>1000) were seen in the Canadian Beaufort (L. Harwood, personal communication[4]; G. Miller, personal communication[5]), but few (n = 16) were seen in the Alaskan Beaufort (Table 11). Bowheads were seen as far east as Amundsen Gulf (71°30'N, 119°50'W), but the majority of sightings in Canada were made north of Kay (69°10'N, 138°20'W) and Shingle (68°55'N, 137°25'W) Points (Figure 14A). Bowheads in the Alaskan Beaufort Sea were seen approximately 0.5 to 89 km offshore in water 7 to 146 m deep ($\bar{x}$ = 48.4, 38.66 s.d., n = 15). Although systematic surveys were flown west to 150°W (Appendix A: Flights 21 and 31), bowheads were seen only as far west as 141° 55'W (Figure 14A).

In the first half of September, four aircraft and research crews were dedicated to surveying for bowheads primarily in the Alaskan Beaufort Sea, with three additional aircraft (LGL-In/Gov, two aircraft, and ESL) surveying in the Canadian Beaufort. Bowheads were seen in Canada as far east as Franklin Bay (70°N, 126°20'W) and again in large numbers (>1000) north of Kay and Shingle Points (L. Harwood, personal communication[4]; G. Miller, personal communication[5]), and there were more bowhead sightings (n = 189) in the Alaskan Beaufort Sea (Figure 14B). Data from the four aircraft surveying in Alaskan waters indicate that bowheads were seen approximately 0.5 to 120 km offshore in water 7 to 1850 m deep ($\bar{x}$ = 81.7, 334.2 s.d., n = 30). Whales were seen as far west

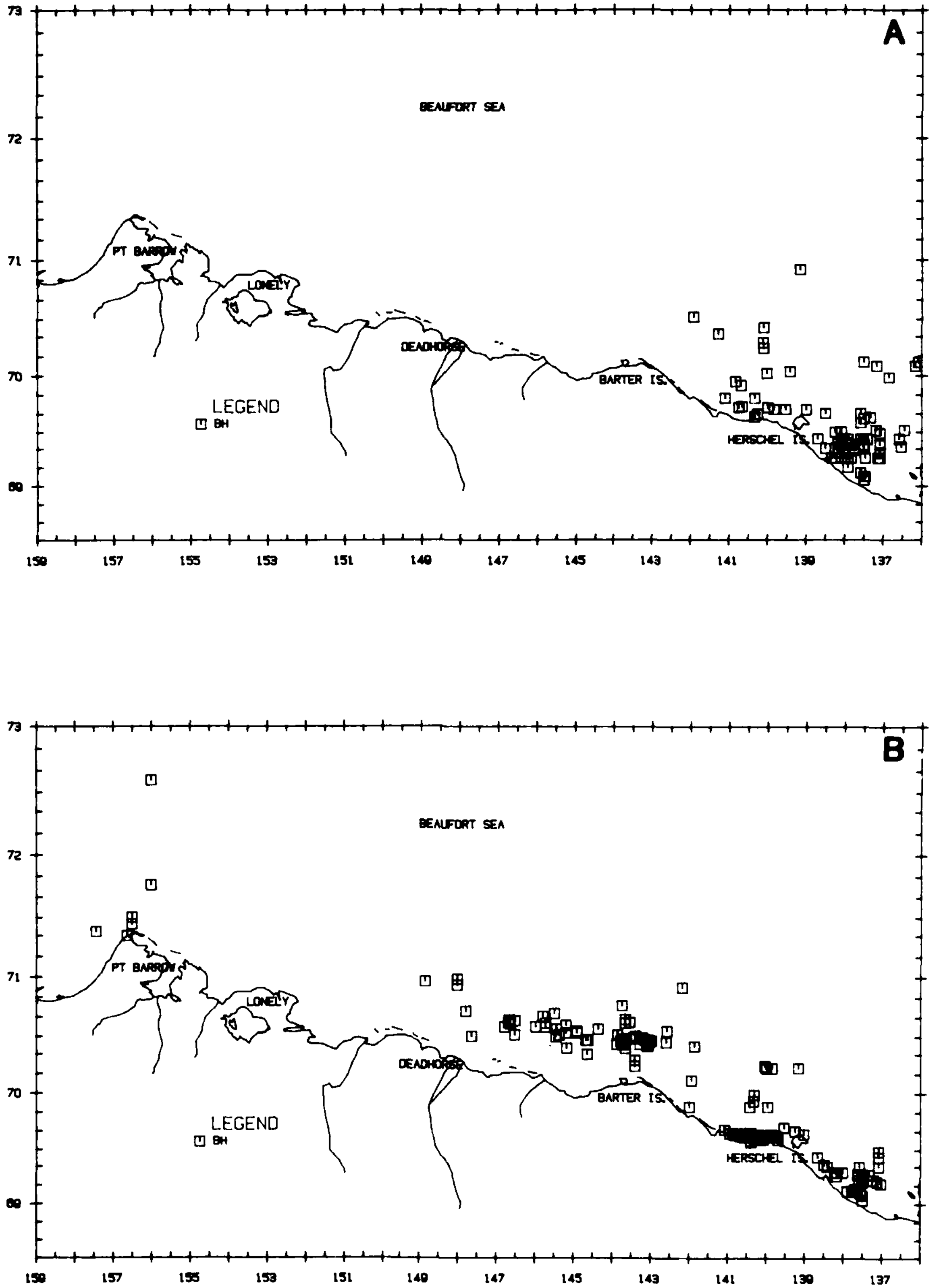
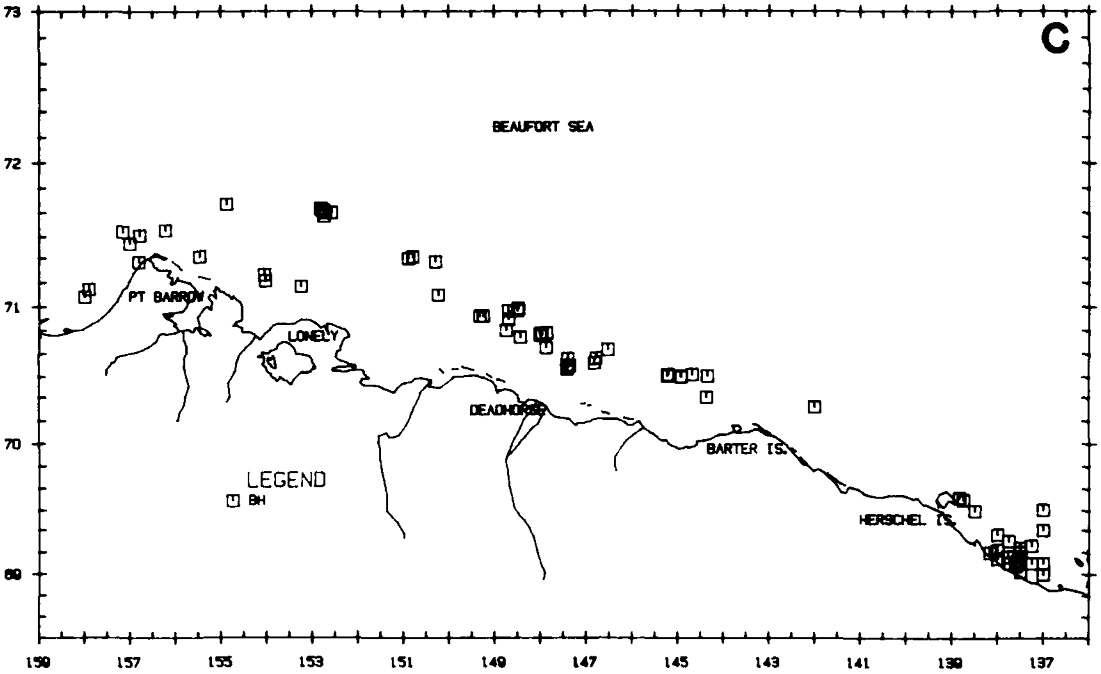


Figure 14. Distribution of 325 sightings of 3008 bowhead whales from the combined data of ten survey aircraft, August-October 1985: 78 sightings of 1187 whales, August (A); 165 sightings of 1607 whales, September (B); (contd next page)



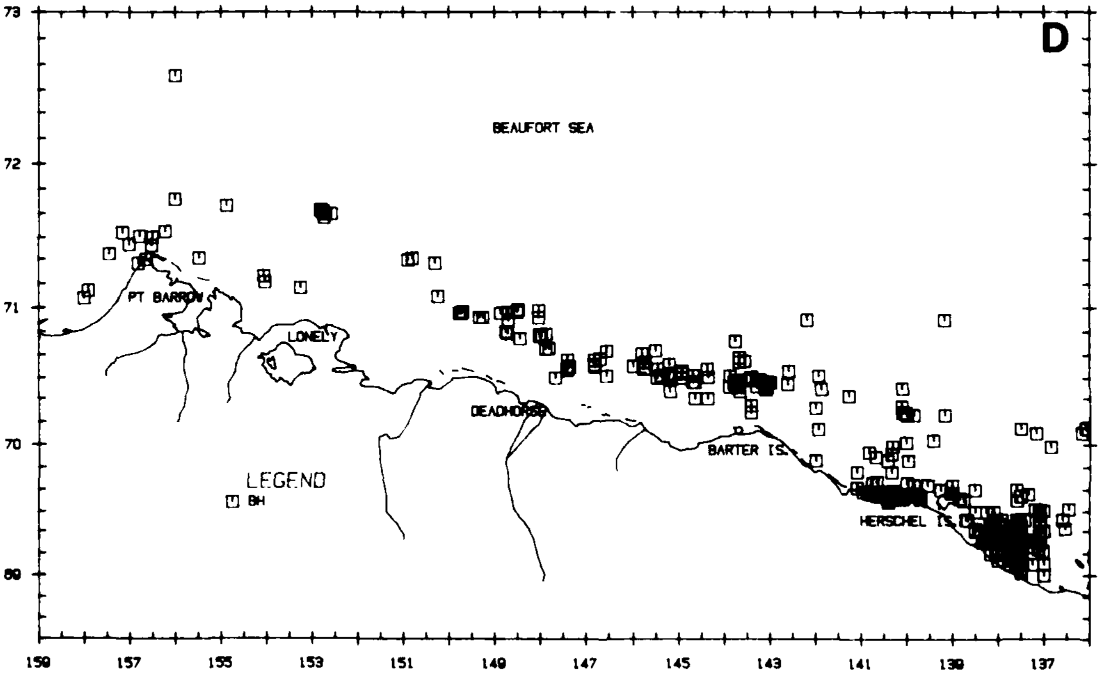


Figure 14 (contd). 82 sightings of 214 whales, October (C); all sightings (D). Note: 61 sightings of 280 whales were not plotted because they were east of 136°W or west of 159°W.

as $146^{o}48'W$ (Figure 14B), although systematic surveys were flown west to $150^{o}W$ (Appendix A: Flight 39). Aggregations of 10 to 25 whales were consistently seen east of Demarcation Bay along Komakuk Beach by researchers on four aircraft (Appendix A: Flights 36 and 37; Appendix C: Flights C-2, C-3 and C-4; Richardson et al., 1985c; L. Harwood, personal communication[4]).

In the latter half of September, there were no crews surveying exclusively in the Canadian Beaufort, but five aircraft and crews were surveying in the Alaskan Beaufort and bowheads were seen between $140^{o}W$ and $149^{o}19'W$ from 0.5 to 78 km offshore (Figure 14B), in water 7 to 387 m deep ($\bar{x}$ = 47.8, 62.6 s.d., n = 79). Three bowheads were seen swimming in a westerly direction in the Alaskan Beaufort Sea on 20 September at $70^{o}32'N$, $145^{o}12'W$ (n = 2; J. Richardson, personal communication[3]) and $70^{o}43'N$, $147^{o}48'W$ (n = 1; S. Johnson, personal communication[6]). These sightings, together with sightings on 22 September (Appendix A: Flight 43), were the first westward migrating bowheads seen since 17 August. As a result, the NMFS officially recognized the onset of the bowhead migration as 24 September (B. Morris, personal communication[7]). No bowheads were seen in the western Alaskan Beaufort Sea (between $149^{o}30'W$ and $157^{o}W$), although transect surveys were flown west to $157^{o}W$ (Appendix A: Flight 45). Surveys in Canada were flown only between $130^{o}30'W$ and $131^{o}30'W$ (L. Harwood, personal communication[4]) and there were no surveys of the western Canadian Beaufort ($136^{o}W$ to 139^{o}) during the latter part of September. Therefore, the presence or absence of bowheads north of Kay and Shingle Points during this time period cannot be verified. Research personnel flying walrus surveys in the far western Alaskan Beaufort ($156^{o}W$ to $157^{o}W$) and northeastern Chukchi Seas between 18 and 30 September saw 13 bowheads between 7 and 140 km offshore (K. Frost, personal communication[2]; Figure 14B and 15). This indicated that either a portion of the bowhead population had migrated from the Canadian Beaufort through the Alaskan Beaufort by mid to late September, or that a segment of the western Arctic stock of bowheads may have never completed a migration to the eastern Canadian Beaufort Sea and instead remained in the Chukchi or Alaskan Beaufort Sea throughout the summer and fall, as suggested by Ljungblad et al. (1983). Bowheads have been sighted in the Chukchi Sea in August and September (Bogoslovskaya et al., 1981; Braham et al., 1984; Moore et al., 1986a; Ray and Wartzok, 1980) and the USFWS sightings may have been of bowheads that were early migrants from only as far as the Alaskan Beaufort Sea.

In October, surveys continued to be flown over the Alaskan Beaufort by three aircraft, and an additional aircraft and crew flew surveys in the western Canadian Beaufort Sea from 7 to 18 October. Sightings were generally farther to the west (Figure 14C), and nine bowheads were sighted in the Chukchi Sea (Appendix A: Flights 58 and 61; K. Frost, personal communication[2]; Figure 15). The aggregation of whales consistently seen east of Demarcation Bay along Komakuk Beach in September was not seen in October, although there were numerous sightings of bowheads (n = 25 to 30) in Canadian waters, particularly between Kay and Shingle Points (J. Richardson, personal communication[3]; Figure 14C). Bowheads have been seen in October in the western Canadian Beaufort Sea in past years (Ljungblad et al., 1985), although not in such substantial numbers. Most October sightings in the Alaskan Beaufort Sea were west of 144°W, between 18 and 92 km offshore and in water 4 to 595 m deep ($\bar{x}$ = 49.9, 85.5 s.d., n = 78). There were no sightings of bowheads made by any aircraft in the Alaskan Beaufort Sea after 17 October, nor in the Canadian Beaufort Sea after 18 October. Extensive survey effort between 139°W and 152°W on 19 and 20 October by three aircraft produced no sightings of bowheads, indicating the majority of the migration had passed.

Despite differences in data-collection techniques and project rationale, the combined sighting data base indicated that the observed migration route across the Alaskan Beaufort Sea was centered roughly shoreward of the continental shelf break generally along the 29 m isobath (see Figure 14D). Combined sighting rates were relatively low in August and through early September, particularly in the Alaskan Beaufort Sea, suggesting that the fall 1985 bowhead migration was somewhat abbreviated and had a later peak period than in some other years (1982, 1983). The 1985 migration was most similar to 1979 when there were peak daily WPUE and peak 5-day SPUE in mid-October (Ljungblad et al., 1985; see Figure 27).

Most whales seen from the primary aircraft (75%, n = 104) were found in shallow (0-50 m) depths throughout the fall (Table 12). Twenty-five percent (n = 35) were found in transitional (51 to 2,000 m) depths and no bowheads were seen in deep water (over 2,000 m). Mean depth at bowhead sightings was 56 m, with the deepest sighting (595 m) that of a group of 18 whales that appeared to be feeding in waters north of Harrison Bay on 6 October (Appendix A: Flight 54).

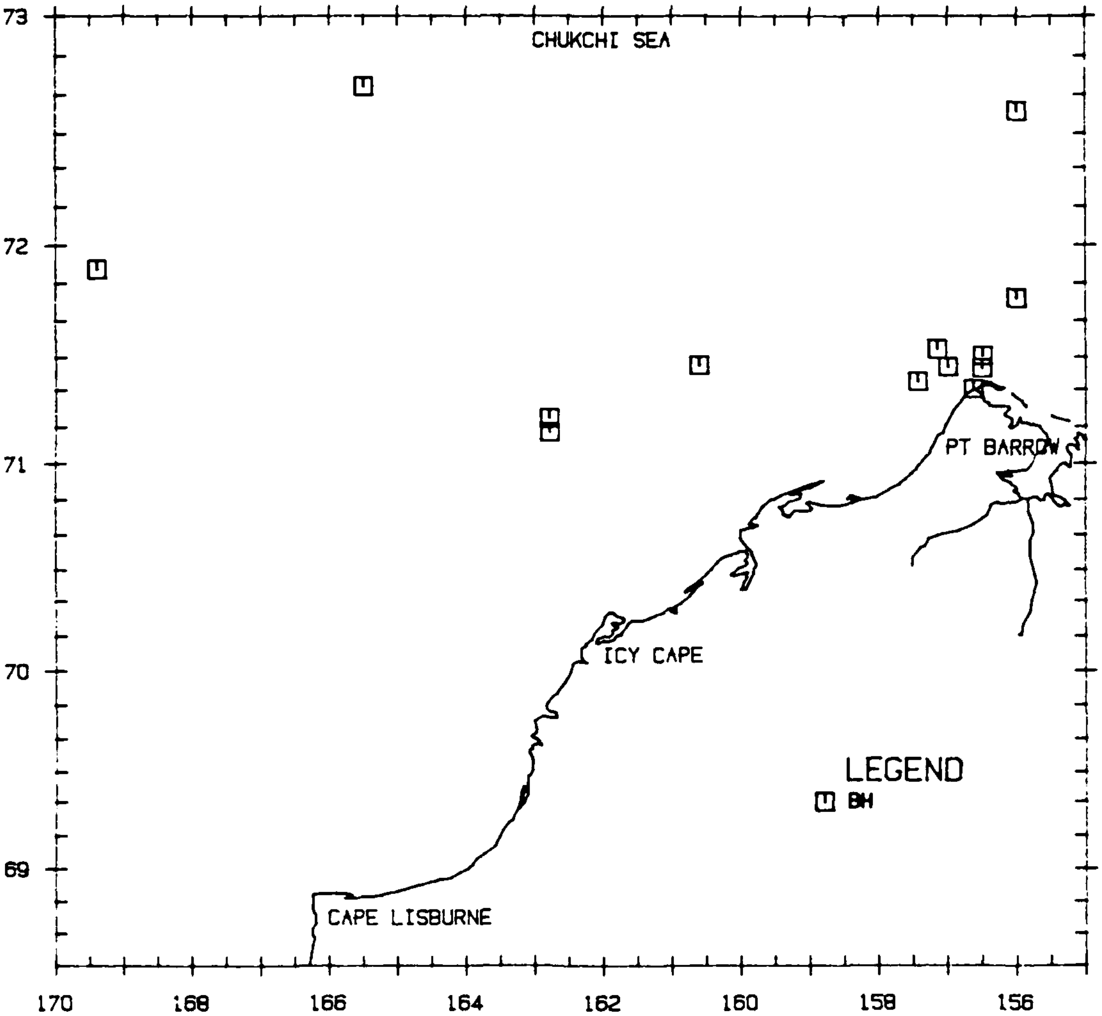


Figure 15. Distribution of 13 USFWS sightings of 19 bowheads in the western Beaufort and northeastern Chukchi Sea, 18 September - 1 October, 1985. All sightings made by observers flying walrus surveys for the USFWS (K. Frost, personal communication[2]).

Bowheads were usually seen in light ice conditions (0 to 30% coverage; 64%, n = 88), or heavy ice conditions (71 to 99% coverage; 33%, n = 47) (Table 13). Bowheads seen in August (9%, n = 12), when ice coverage was heavy in all areas of the Alaskan Beaufort Sea, were in relatively ice free water (0-5%) north and east of Herschel Island. Most whales (61%, n = 41) seen in September were in open ($\leq$1% ice) water with the remainder seen in 21 to 40 percent coverage (33%, n = 22) and 81 to 90 percent coverage (6%, n = 4). Bowheads seen in October were mainly (71%, n = 43) in $\geq$71 percent ice as most of the Beaufort Sea was frozen over.

Table 12. Bimonthly summary of depths at bowhead sightings, fall 1985.

	1-15 Aug No.(%)	16-31 Aug No.(%)	1-15 Sep No.(%)	16-30 Sep No.(%)	1-23 Oct No.(%)	Total No.(%)
Shallow (0-50 m)	4(44)	2(67)	34(100)	31(94)	33(55)	104(75)
Transition (51-2,000 m)	5(56)	1(33)	0	2(6)	27(45)	35(25)
Deep (over 2,000 m)	0	0	0	0	0	0
TOTAL	9	3	34	33	60	139

Table 13. Number and percent of bowheads found in each ice coverage class, fall 1985.

Ice Coverage (%)	1-15 Aug No.(%)	16-31 Aug No.(%)	1-15 Sep No.(%)	16-30 Sep No.(%)	1-23 Oct No.(%)	Total No.(%)
0-10	9 (100)	3 (100)	34 (100)	7 (21)	15 (25)	68 (49)
11-20	0	0	0	0	1 (2)	1 (1)
21-30	0	0	0	19 (58)	0	19 (14)
31-40	0	0	0	3 (9)	0	3 (2)
41-50	0	0	0	0	0	0
51-60	0	0	0	0	0	0
61-70	0	0	0	0	1 (2)	1 (1)
71-80	0	0	0	0	29 (48)	29 (21)
81-90	0	0	0	4 (12)	1 (2)	5 (3)
91-99	0	0	0	0	13 (21)	13 (9)
TOTAL	9	3	34	33	60	139

b. **Temporal Distribution of Bowheads in Relation to OCS Drilling Activities**

Five OCS drill sites were active at various times during fall 1985 (Table 14). Activity at and near these sites included actual drilling procedures (drilling, casing, cementing, logging, testing) as well as daily helicopter and vessel (tugboats and icebreakers) support efforts. Very little actual drilling took place between August and October; the majority of activity involved support efforts by helicopters and vessels. All drill sites were located between 143°W and 153°W. Bimonthly bowhead sightings collected from all research crews conducting studies in the Alaskan Beaufort Sea were plotted within this 10° window for September and October to exhibit the spatial and temporal distribution of whales in relation to these OCS drilling activities (Figure 16A-C). Whale sightings near drill sites were not plotted in August because all sightings were east of 143°W.

The concrete island drilling structure (CIDS) was anchored at Orion Prospect near Point Lonely and preparatory activity was taking place there as well as on Sandpiper Island by 1 August. The drillship Canmar Explorer II arrived at Hammerhead Prospect on 6 August. All bowheads seen in August were well to the east of these sites; the closest bowhead sighting was of one whale 166 km east of Hammerhead Prospect (Appendix A: Flight 22).

The same three sites remained active between 1 and 15 September. As in August, Orion Prospect and Sandpiper Island had only support activities taking place, but Hammerhead Prospect carried out logging, casing, cementing, and testing procedures (Table 14). Nine sightings of 16 bowheads were made by crews aboard two survey aircraft between 143°W and 153°W (Figure 16A). Bowheads were sighted 18 to 77 km from Hammerhead Prospect (Appendix A: Flights 37 and 39; J. Richardson, personal communication[3]). All whales were either northeast or northwest of the drilling site (Figure 16A); no bowheads were seen south of the drillship between it and the shoreline. All bowhead sightings during this period were well east of Sandpiper Island and Orion Prospect; the closest whales to these sites were 85 and 197 km distant, respectively (J. Richardson, personal communication[3]). In late September, four drill sites were active, including Orion Prospect, Sandpiper Island, Hammerhead Prospect and Corona Prospect, to which the Canmar Explorer II drillship was moved after work was completed at Hammerhead Prospect. Orion and Sandpiper again had only support activity taking place, but Hammerhead was drilling between 22 and 24 September and Corona was drilling between 25 and 28 September. Sixty-five sightings of 161 bowheads were

Table 14. Summary of five OCS drilling site positions, periods of activity, and closest bowhead whale sighting, fall 1985.

Site Identifier	Type of drilling site	Position (Lat N, Long W)	Period of Drilling Activity	Total Period of Activity (including helicopter and vessel support)	Closest Bowhead Sighting (date and distance)
Orion Prospect	concrete island drilling structure (CIDS)	70°57.2 152°03.8	began drilling in Nov.	on site 1 Aug	6 Oct 59.5 km NE
Sandpiper Island	artificial island	70°35.4 149°05.5	began drilling 13 Oct	on site 1 Aug	6 Oct 32.6 km NNE
Hammerhead Prospect	drillship-Canmar Explorer II	70°21.6 146°21.3	8-17 Aug; 22 Aug - 16 Sept; 22 Sept - 24 Sept	6 Aug - 24 Sept	11 Sept 18.6 km NW
Corona Prospect	drillship-Canmar Explorer II	70°18.9, 144°49.7	25-28 Sept; 3-4 Oct	25 Sept - 20 Oct	23 Sept 16 km NNE
Erik Prospect	drillship-Canmar Explorer II	70°20.7 143°58.8	5 Oct; 13-14 Oct	5-14 Oct	7 Oct 14.5 km W

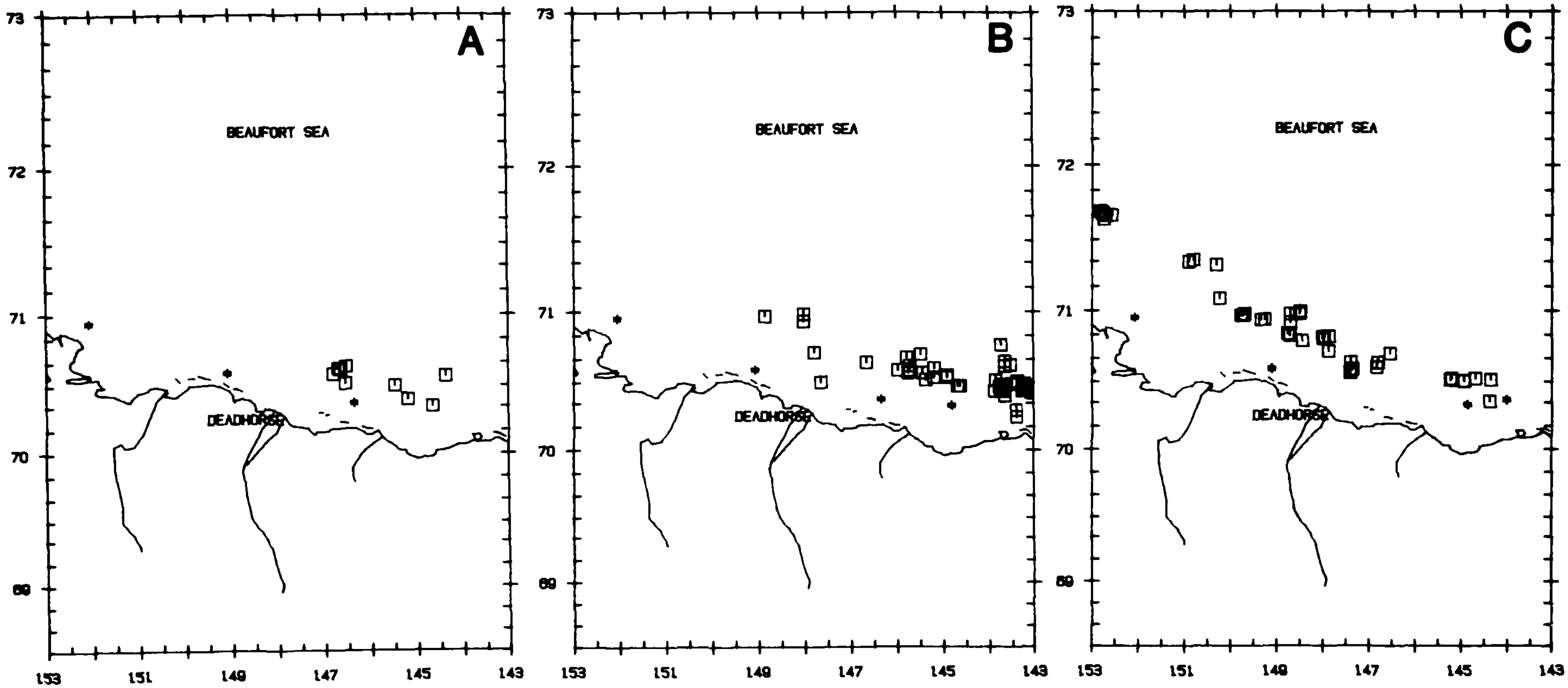


Figure 16. Distribution of 121 sightings of 261 bowhead near five OCS drilling sites (*), fall 1985: 9 sightings of 16 bowheads, 1-15 September (A); 65 sightings of 161 bowheads, 16-30 September (B); 47 sightings of 84 bowheads, 1-20 October (C). Data represents the combined sightings of five survey aircraft. Bowheads were not plotted for August because all sightings were east of 143°W. Drilling sites were plotted only when operative; see Table 14 for dates of operation.

made in the area between 143°W and 153°W by crews aboard five survey aircraft between 16 and 30 September (Figure 16B). Bowheads were seen 16 to 68 km north and east of Corona Prospect (Appendix A: Flights 46 to 48; Appendix C: Flight C-11; J. Richardson, personal communication[3]), and 28.5 to 49 km northeast of Hammerhead (Appendix A: Flight 47; J. Richardson, personal communication[3]). Bowheads were also sighted 43 to 59 km north of Sandpiper Island (S. Johnson, personal communication[6]), but none were seen near Orion Prospect.

In October, support activities continued to take place at Orion Prospect, and Sandpiper Island began to drill on 13 October. The Canmar Explorer II drillship divided its time between Corona Prospect and Erik Prospect, only 32 km apart. Forty-seven sightings of 84 bowheads were made by crews aboard three survey aircraft between 143°W and 153° in October (Figure 16C). Bowheads were generally seen north of all drill sites. Closest whale sightings were 59.5 km from Orion Prospect (Appendix A: Flight 54), 32 to 50 km directly north of Sandpiper Island (Appendix A: Flight 53; S. Johnson personal communication[6]), and 14 to 28 km from both Erik and Corona Prospects, including one whale seen directly between the two sites on 7 October (J. Richardson, personal communication[3]; Figure 16C). There was no actual drilling activity taking place at either site on that day due to ice conditions and the whale migration, but vessel and helicopter support activities were going on.

The effects of underwater noise generated by industrial operations on bowheads may be manifested relatively far from their source because sound travels very efficiently in water (Urick, 1983). The underwater sound fields around offshore drilling sites are comprised of the combined noise generated by support vessels, helicopter and fixed wing aircraft overflights, drilling activities, and occasionally icebreakers (Gales, 1982; Greene, 1985; Moore et al., 1984). Peak noise levels from these industrial sources are generally low frequency (<500 Hz), and are comprised of a variety of spectral components that are described as either a) broadband "rumbling" sounds that are not concentrated at any particular frequency, or b) narrowband tonal sounds that are concentrated at frequencies associated with rates of machinery operation events (e.g.,propeller rotation rate). Overall, the industrial noise associated with shallow water drilling sites, such as those listed in Table 14, is roughly 25 dB above median ambient noise level at 1 km radius and 10 dB above median ambient level at 10 km radius (Greene, 1985). As a result, bowheads seen closest (14.5 to 18.6 km) to the three easternmost drilling

sites could probably detect underwater noise associated with the ongoing industrial activities. Because bowhead distribution near these sites was not appreciably different from that of prior years, it does not appear that industrial noise affected whale movements.

Behavior and Sound Production

Forty-four percent (n = 61) of all whales seen were either swimming or diving (Table 15). Bowhead swimming direction was not significantly clustered around a mean heading in August (Figure 17). In September, headings were significantly clustered around a mean of 286°T, and in October there was significant clustering around a mean heading of 276°T, for a total combined heading of 279° for whales seen in the Beaufort Sea. In the Chukchi Sea in October, bowhead swim direction (n = 2) was not significantly clustered around any mean heading. Bowheads not migrating were resting (11%, n = 15), feeding (25%, n = 35), milling (7%, n = 9), part of cow-calf association (9%, n = 12) or displaying (5%, n = 7). One solitary calf was seen resting at the surface without an adult (Appendix A: Flight 17).

Feeding bowheads were seen on two occasions. The first group, of 23 to 25 adults, was seen on 9 September (Appendix A: Flight 36) within 0.5 km of shore between 139°45'W and 140°41'W. The second feeding group was seen on 6 October (Appendix A: Flight 54) at 71°20'N, 150°47'W and contained 18 to 20 individuals, including three calves that were each closely associated with an adult. This group was located near the shelf break north of Harrison Bay and was in 80 percent ice. Milling, repeated dives and defecation were among the behaviors exhibited by each group, and mud and sediment were evident on the surface.

Two bowheads, among a group of four westerly swimming whales, were seen breaching on 5 October (Appendix A: Flight 53). Both whales were swimming when initially sighted and then began series of breaches. The two whales accompanying the breaching whales continued swimming with no apparent change in speed or direction. Bowheads were seen tail slapping twice in August and twice in September, and one whale was observed rolling (Appendix A: Flight 48).

Most bowheads (67%, n = 93) were swimming at slow (<2 km/hr) to medium (2 to 4 km/hr) speeds and none were observed swimming fast (>4 km/hr) (Table 16). Thirty-one percent (n = 43) were still.

Table 15. Bimonthly summary of bowhead behavior, fall 1985.

	1-15 Aug No.(%)	16-31 Aug No.(%)	1-15 Sep No.(%)	16-30 Sep No.(%)	1-23 Oct No.(%)	Total No.(%)
MIGRATORY						
Swim	5(56)	3(100)	3(9)	17(52)	30(50)	58(42)
Dive	0	0	0	2(6)	1(2)	3(2)
SOCIAL						
Rest	2(22)	0	2(6)	5(15)	6(10)	15(11)
Feed	0	0	23(68)	0	12(20)	35(25)
Mill	0	0	6(18)	2(6)	1(2)	9(6)
Cow-Calf	0	0	0	6(18)	6(10)	12(9)
Display	2(22)	0	0	1(3)	4(6)	7(5)
TOTAL	9	3	34	33	60	139

Table 16. Bimonthly summary of bowhead swimming speeds, fall 1985.

	1-15 Aug No.(%)	16-31 Aug No.(%)	1-15 Sep No.(%)	16-30 Sep No.(%)	1-24 Oct No.(%)	Total No.(%)
Still 0 km/hr	3(33)	--	3(9)	9(27)	28(47)	43(31)
Slow < 2 km/hr	5(56)	3(100)	30(88)	20(61)	19(32)	77(55)
Medium 2-4 km/hr	--	--	1(3)	4(12)	11(18)	16(12)
Fast >4 km/hr	--	--	--	--	--	0(0)
Unknown	1(11)	--	--	--	2(3)	3(2)
TOTAL	9	3	34	33	60	139

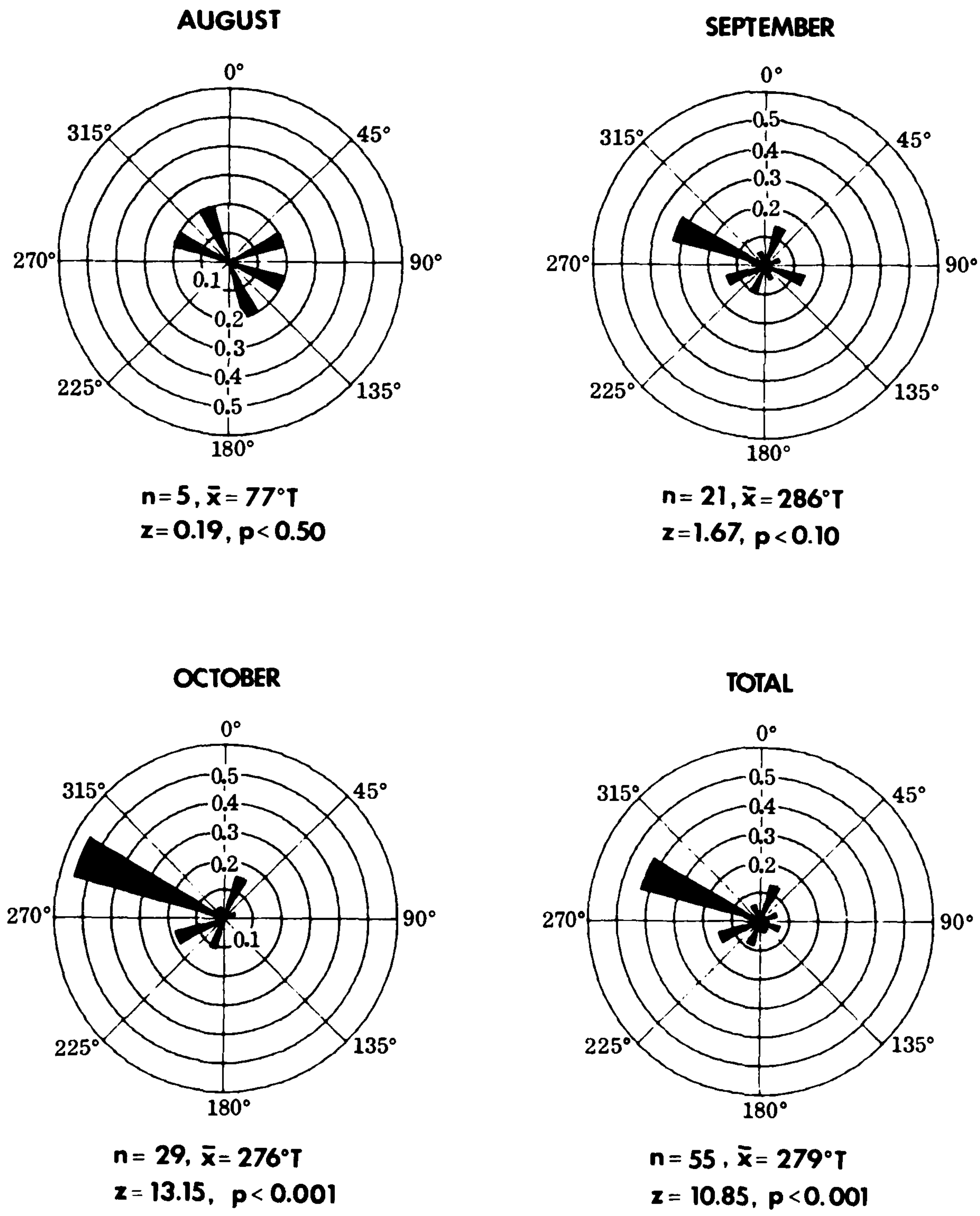


Figure 17. Bowhead swimming direction analysis, fall 1985.

Table 17. Bimonthly summary of bowhead whale response to aircraft, fall 1985.

	1-15 Aug No.(%)	16-31 Aug No.(%)	1-15 Sep No.(%)	16-30 Sep No.(%)	1-23 Oct No.(%)	Total No.(%)
Positive	0	0	3(9)	6(18)	0	9(6)
Negative	9(100)	3(100)	31(91)	27(82)	60(100)	130(94)
Total	9	3	34	33	60	139

Fewer (6%, n = 9) bowheads were judged to react to the aircraft (Table 17) this year than in all previous years (Ljungblad et al., 1985). The mean altitude at which bowheads responded to the aircraft (409 m) was not significantly lower than the mean altitude for all other sightings (415 m, $t = 0.165$, $p < 0.50$). Positive responses were all from adults, and all but one were from whales in light ice coverage (< 10%). The exception was one bowhead closely associated with another whale, which did not react to the aircraft, in 90 percent ice.

Eleven sonobuoys were dropped during the fall season near bowhead whales or vessels (Table 18). Bowhead whale calls were recorded on 11 September and 23 September onboard the secondary aircraft (N545N) assessing bowhead migration status (Appendix C: Flights C-2 and C-8), and on 25 September, 27 September, and 13 October on board N780 (Appendix A: Flights 46, 48 and 59). Bowhead calls and were aurally analyzed (i.e., subjective listening) as in past years (Ljungblad et al., 1983, 1984a) and placed into simple or complex moan categories. Simple moans were tonal, frequency modulated (FM) sounds often with harmonic structure and usually in the 50 Hz to 2 kHz frequency band. Simple moans were classified to five categories based upon temporal frequency modulation as follows:

FM_1 up = ascending frequency modulation

FM_2 down = descending frequency modulation

FM_3 constant = no discernable frequency modulation

FM_4 inflect = combined ascending and descending frequency modulation

FM_5 high = short calls starting above 800 Hz

Table 18. Summary of sonobuoy drops, fall 1985.
*Dropped during N545N Surveys (Appendix C)

Date	Latitude (N)	Longitude (W)	Subject
28 Aug	70°20.7'	141°43.2'	Vessel
11 Sep*	69°37.8'	140°31.7'	Bowhead
13 Sep	70°36.5'	146°36.0'	Bowhead
13 Sep*	70°22.8'	145°58.2'	Drillship
13 Sep*	69°38.9'	140°50.5'	Bowhead
23 Sep*	69°36.5'	140°20.4'	Bowhead
25 Sep	70°26.9'	143°45.7'	Bowhead
27 Sep	70°27.1'	143°07.7'	Bowhead
1 Oct	71°39.4'	152°42.9'	Bowhead
5 Oct	70°57.6'	149°43.7'	Bowhead
13 Oct	70°48.6'	147°58.4'	Bowhead

Complex moans were amplitude modulated (AM) sounds. Amplitude modulation may be rapid resulting in well-defined components (Watkins, 1967), or slow, resulting in non-uniform and varied component structure. Two categories of complex moans aurally recognized on the basis of frequency content were

AM_1 growl = low frequency calls with energy primarily below 1 kHz

AM_2 trumpet = high frequency calls with energy primarily between 500 Hz and 4 kHz

Growls can (and do) grade into trumpets with a shift in frequency. Occasionally simple or complex moans exhibit both FM and AM components. Aurally these calls sound "complex" and were so categorized for the purpose of this analysis.

To standardize call counts over recording periods of varying duration, a call rate was derived as calls per whale-hour (calls/wh-h) by dividing the number of calls by the duration of the recording period and by the number of bowheads seen within about 10 km (5.4 nmi) of the sonobuoy. A 10-km radius around the sonobuoy was used to derive the possible number of calling whales based upon the Cummings and Holliday (1983) estimate of signal/noise ratios of bowhead calls approaching

zero at about 5 to 15 km. Call rate, so derived, is useful only as a relative index of overall calling behavior because its accuracy is dependent on a precise count of the number of whales near enough to the sonobuoy to be recorded. The whale-to-sonobuoy distance will vary somewhat with each location based upon sound propogation loss parameters that are dependent upon environmental factors such as water depth, ice coverage, and sea state (Urick, 1983). To compare call samples recorded near whales involved in a variety of behaviors, a behavioral index was derived by ranking behaviors by their general surface activity level, then multiplying the rank by the number of surfaced whales seen within 10 km of the sonobuoy exhibiting that behavior and dividing by the number of whales. Behaviors were ranked and abbreviated as follows:

0 = resting (RE)
1 = swimming or diving (SW or DV)
2 = milling or mild social (ML or MS)
3 = feeding (FE)
4 = cow/calf association (CC)
5 = active social or play (AS or PL)
6 = display (DY)

These rankings attempted to reflect the relative level of exertion required of the whale involved in the behavior.

Of a sound sample containing 170 discrete calls, 61 percent were simple moans and 39 percent were complex moans (Table 19). The four most common call types were growl (35%), down (25%), up (19%) and inflect (11%). It appears that resting or swimming bowheads produce mostly tonal FM calls, and that complex AM sound production increases with increasing levels of social behavior (Ljungblad et al., 1984; Würsig et al., 1985). This assertion appears to be generally true of the 1985 sound sample. The combined proportion of simple FM calls were greatest on 23 September (77%) when whales were swimming and milling, and on 25 September (87%) when resting and swimming whales were seen. Conversely, complex AM calls were prevalent on 11 September (56%) when whales were resting, feeding and involved in mild social behaviors, and on 27 September (54%) when a sonobuoy was dropped near swimming and mildly social whales that included a cow-calf pair. The relatively high proportion of complex calls (53%) recorded on 13 October, when no

Table 19. Results of initial aural analysis of recorded bowhead calls, fall 1985. No. (%) = Number (percent).

						CALL TYPE								
						Simple					Complex			
Date	Sample Duration[1]	No. Whales	General Behavior[2]	Behavior Index	Call Rate[3]	Up No. (%)	Down No. (%)	Const No. (%)	Inflect No. (%)	High No. (%)	Growl No. (%)	Trumpet No. (%)	Total No.	Comment
11 Sept[4]	0.72	18	RE/MS/FE	1.7	0.7	1(11)			3(33)		5(56)		9	distant airgun noise
23 Sept[4]	0.23	8	SW/ML	1.5	16.3	14(47)	8(27)			1(3)	7(23)		30	relatively loud ambient noise
25 Sept	0.45	4	RE/SW	0.5	21.1	9(24)	11(29)	3(8)	8(21)	2(5)	5(13)		38	water noise
27 Sept	0.33	11	SW/MS/CC	2.1	14.6	8(15)	9(17)	1(2)	4(8)	2(4)	29(54)		53	belukha calls, a/c noise
13 Oct	0.20	6	RE/SW	0.8	33.3	1(2)	14(35)	1(2)	3(8)		14(35)	7(18)	40	95% ice coverage, a/c noise
Total	1.93	47			1.9	33(19)	42(25)	5(3)	18(11)	5(3)	60(35)	7(4)	170	

1) Sample duration in hours

2) Abbreviation Key, p. 58

3) Call rate = $\dfrac{\text{No. calls/sample duration (h)}}{\text{No. Whales}}$

4) Recordings made on N545N surveys (Appendix C)

Table 20. Summary of bowhead calf sightings, fall 1985.

Date	Flt	Latitude (°N)	Longitude (°W)	Heading (°M)	Behavior
8 Aug	17	70°13.8'	140°06.1'	--	resting at surface alone
27 Sept	48	70°26.7'	143°06.6'	210	swimming close to cow
27 Sept	48	70°27.1'	143°07.7'	340	swimming in group of 3
27 Sept	48	70°27.8'	143°14.0'	210	swimming in group of 5
6 Oct	54	71°20.5'	150°47.4'	--	resting at surface in group of feeding whales
6 Oct	54	71°20.5'	150°47.4'	--	resting at surface in group of feeding whales
6 Oct	54	71°20.5'	150°47.4'	--	resting at surface in groups of feeding whales

"social whales" were seen, underscores the difficulty of definitely ascribing call types to behavior; either the whales making the complex calls went unseen, or the assumption that only "social whales" are complex call producers is a shaky one. A regression analysis revealed no significant correlations between call types, nor between behavior index and call types. There was a significant correlation between call rate and the FM_2 call type ($r = 0.942$, $p < 0.005$, $n = 5$) indicating that as call rate increases more "down" calls are produced. In addition, there was a trend for call rate to be negatively correlated with the number of whales ($r = -0.858$, $p < 0.10$, $n = 5$), indicating that a higher call rate may not correspond to relatively more whales (i.e. not all whales seen are calling).

Recruitment

Seven calves were among the total of 139 bowheads seen from the primary aircraft (N780), resulting in a GARR of 5.04 percent (Table 20). This estimate was higher than for any fall except 1982 (Ljungblad et al., 1985). One solitary calf was seen on 8 August (Appendix A: Flight 17). Three calves were seen on 27 September (Appendix A: Flight 48), and 3 calves were seen on 6 October within

a group of 18 bowheads presumed to be feeding (Appendix A: Flight 54). The crew aboard the aircraft assessing bowhead migratory status (N545N) sighted 5 calves among 106 whales (Appendix C: Table C-4), yielding a combined GARR of 4.90 percent for the two aircraft. This combined recruitment estimate was nearly identical to the 4.87 estimate calculated for the 1982-85 combined sightings from primary and secondary aircraft surveying for bowheads in the Alaskan Beaufort Sea (Clarke et al., 1986).

Other Species

Belukha Whale

One hundred sixteen sightings of 439 belukhas were made by the primary aircraft (N780), and six sightings of 54 belukhas were made by the secondary aircraft (N545N; Appendix C) in fall (Figure 18). Belukhas were seen both singly and in groups of 2 to 28. The majority of belukhas (98%, n = 483) seen were swimming, and 8.1 percent (n = 40) were judged to be calves.

Belukha whale distribution during the fall was generally north of the bowhead distribution, although there was overlap in near-shore areas. Belukhas were sighted in depths ranging from 5 to 2868 m ($\bar{x}$ = 446.5 m), significantly deeper than depths in which bowheads were sighted ($\bar{x}$ = 56.2 m, $t = 5.102$, df = 171, $p < 0.001$). Belukha headings were nonsystematic until September when there was significant clustering about a mean heading of 263°T ($z = 6.95$, $p < 0.001$). Belukhas sighted in October in both the Beaufort and Chukchi Seas maintained mostly westerly headings ($\bar{x}$ = 254°T, $z = 4.46$, $p < 0.01$).

Pinnipeds

Nineteen bearded seals and one ringed seal were seen during the fall, fewer than have been seen in any previous season (Ljungblad, 1981; Ljungblad et al., 1980, 1982, 1983, 1984a, 1985b). Seventy-one percent (n = 50) of all pinnipeds seen could not be positively identified.

Polar Bear

Six polar bears were seen by the primary aircraft in late September and October. One bear was seen on 25 September, 60 km north of Barter Island at 70°36.3'N, 143°22.9'W (Appendix A: Flight 46). Two bears were seen on 10 October in the Chukchi Sea; one on 50 percent ice at 71°11.8'N, 164°21.5'W, and

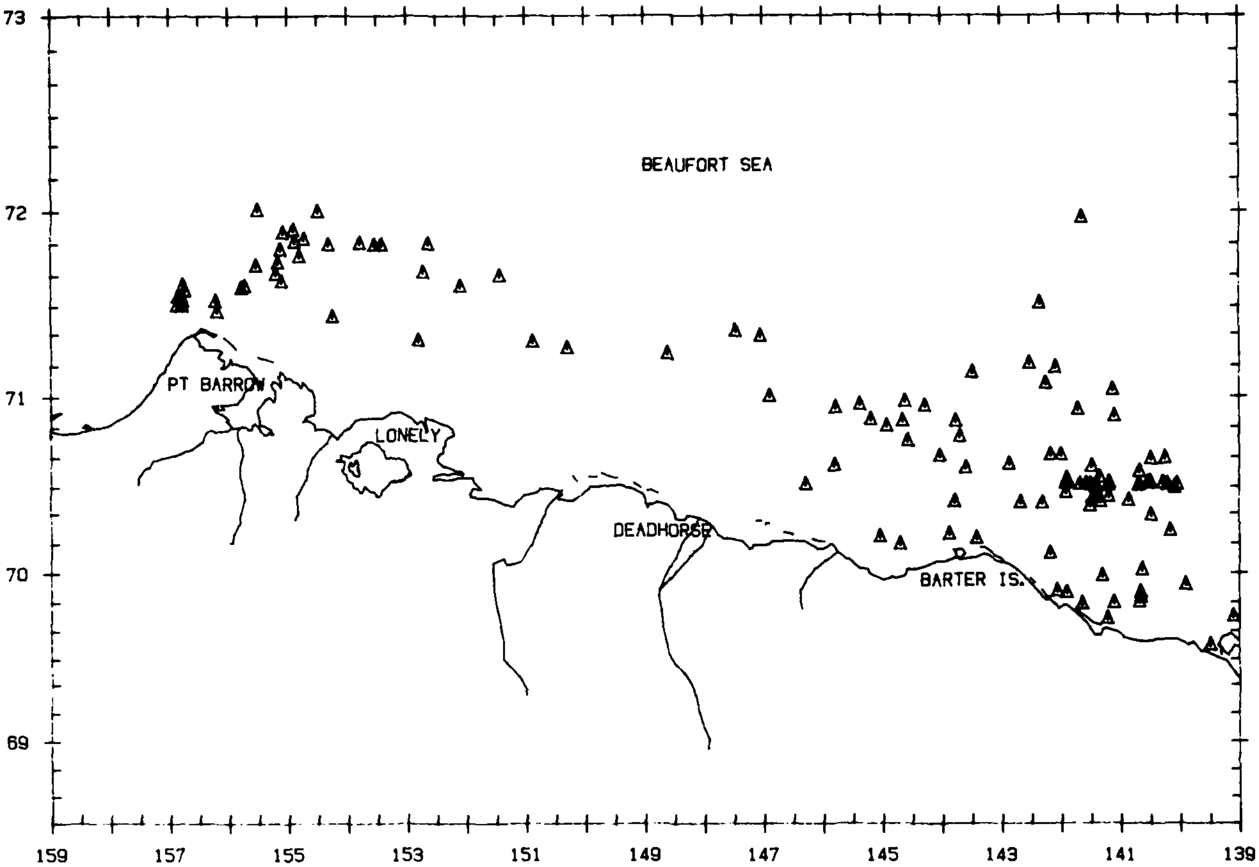


Figure 18. Distribution of 122 sightings of 493 belukha whales, incorporating sightings from both primary and secondary aircrafts, fall 1985.

one on 98 percent ice at 71°16.6'N, 162°21.8'W (Appendix A: Flight 56). Three bears, a sow, and two large cubs were seen in the western Beaufort Sea on 16 October at 71°28.8'N, 154°16.4'W (Appendix A: Flight 62). The secondary aircraft sighted five bears during September (Appendix C: Flights C-7 and C-9).

CONCLUSIONS AND REVIEW 1979-85

This section represents a review and synthesis of data gathered on aerial surveys of endangered whales conducted from 1979 to 1985. Results of these surveys have appeared in annual reports finalized as NOSC technical documents or technical reports (Ljungblad 1981; Ljungblad et al., 1980, 1982, 1983, 1984a, 1985) and in summary manuscripts presented in the proceedings of the International Whaling Commission (IWC) annual meetings (Ljungblad et al., 1986a, 1986b; Moore et al., 1986a, 1986b).

The objectives and methods of data collection and analysis on the primary aircraft (N780) have remained similar throughout all years with the exception of the use of a microcomputer aboard the aircraft since 1982 to record and later analyze data. Bowhead and gray whales have been the principal species studied over the years due to their endangered status and are the only species addressed in this review. Sightings of all other marine mammals may be referenced in the annual reports.

This review follows the seasonal format of the field efforts, i.e., summer (June, July) and fall (August, September, October, November). This was the first year since 1979 that surveys were not flown in spring (April, May). A review of six years of spring survey efforts and results was presented in Ljungblad et al. (1985). The objectives for each season are briefly stated prior to presentation of the summary data.

SUMMER (June, July)

The primary objectives of summer aerial surveys have been to determine the distribution, relative abundance, and behavior of gray whales in the northern Bering Sea and the southern and coastal Chukchi Sea. Secondarily, surveys were conducted in the Beaufort Sea to search for bowhead whales and/or assess ice conditions.

Survey Effort and Conditions Summary

A total of 354.3 survey hours have been flown in summer since 1980, with 32 percent (114.6 h) of this effort in the Beaufort Sea, 32 percent (112.2 h) in the Chukchi Sea, and 36 percent (127.5 h) in the northern Bering Sea (Table 21). There

Table 21. Summary of of flight effort (hours:minutes) by sea, summer 1980-85.

	1980	1981	1982	1983	1984	1985	Total	(%)
Bering Sea	1:35	63:47	31:20	22:36	3:22	4:50	127:30	(36)
Chukchi Sea	6:54	39:46	13:11	3:23	14:59	34:01	112:14	(32)
Beaufort Sea	83:55	5:15	1:31	2:10	13:16	8:30	114:37	(32)
TOTAL	92:24	108:48	46:02	28:09	31:37	42:21	354:21	(100)

were no summer surveys flown in 1979, and surveys were conducted in June only in 1980 and 1981. In 1980, search surveys directed toward finding bowhead whales were flown mostly in the Beaufort and northeastern Chukchi Sea. Since 1981, transect and/or search surveys have been flown in the Bering, Chukchi, and Beaufort Seas. Since 1982, surveys have begun on or after 10 July.

Summer ice conditions ranged from open water in the northern Bering and southern Chukchi Seas to over 90 percent coverage in the Beaufort Sea. In the northern Chukchi Sea (north of 70°N), ice conditions often changed dramatically during this period. In general, heavy ice coverage (≥90 percent) was found near-shore between Barrow and Wainwright through mid-July, diminishing to about 70 percent by 31 July. Between Wainwright and Icy Cape, ice coverage ranged from 90 to 60 percent in mid-July, diminishing to open water to 30 percent at Icy Cape and 50 to 70 percent coverage at Wainwright by 31 July. In the Beaufort Sea, near-shore (≤10 km) areas were often ice-free, while offshore coverage ranged from 70 to 90 percent throughout the summer.

Sea states encountered on surveys in the northern Bering and southern Chukchi Seas ranged from 00 to 06, with 01 to 03 conditions the most common. Surveys were terminated when Beaufort 05 to 06 conditions persisted. Sea states in the northern Chukchi Sea and Beaufort Sea generally ranged from 00 to 03 throughout the summer due to the dampening influence of the predominant heavy ice coverage.

Fog and rain dominated summer weather conditions. Due to temperature fluctuations over land and ice, and/or recently ice-free water, low fog often caused surveys to be truncated or aborted.

BOWHEAD WHALE

Distribution

Fifteen sightings of 16 bowheads were made in June 1980. The distribution of whales was roughly from 71°20'N to 71°39'N, between 147°40'W and 141°15'W (Figure 19). This distribution was probably strongly influenced by nearly continuous pan and shorefast ice coverage (i.e. 99-100%) south of 71°20'N. Bowheads were never seen in the Alaskan Beaufort Sea on July surveys.

Habitat Relationships and Behavior

Bowheads seen in June were generally in heavy ice ($\geq$90%), although data on ice type and coverage was not routinely recorded for each sighting in 1980. Depth at bowhead sightings ranged from 2261 m to 3212 m ($\bar{x}$ = 2880 m, 288 s.d.), reflecting the offshore shorefast ice-influenced distribution.

Most whales seen in June were migrating eastward ($\bar{x}$ = 83°T, $z = 8.12$, $p < 0.001$). Swimming (12%, n = 2) and diving (75%, n = 12) comprised the majority of behaviors seen. One whale was seen breaching (6%) and one whale was resting (6%) during this time period. These behavioral indices are similar to those reported for bowheads migrating through the Alaskan Beaufort Sea in April and May (Ljungblad et al., 1985).

GRAY WHALE

Distribution and Density

Eight hundred fifty-three sightings of 2490 gray whales were made over six survey seasons: 58 sightings of 152 whales were made in June 1981 (Figure 20A), and 795 sightings of 2338 whales were made on surveys conducted in July 1980-85 (Figure 20B). As previously mentioned, surveys were conducted only in the Beaufort Sea in June 1980 and no gray whales were seen there.

The highest annual gray whale density estimates (Figure 21), calculated for the month of July 1980-85, were localized in two areas:

(1) the Chirikov Basin north of Saint Lawrence Island where highest annual densities ranged from 0.360 to 1.70 whales/km^2, and

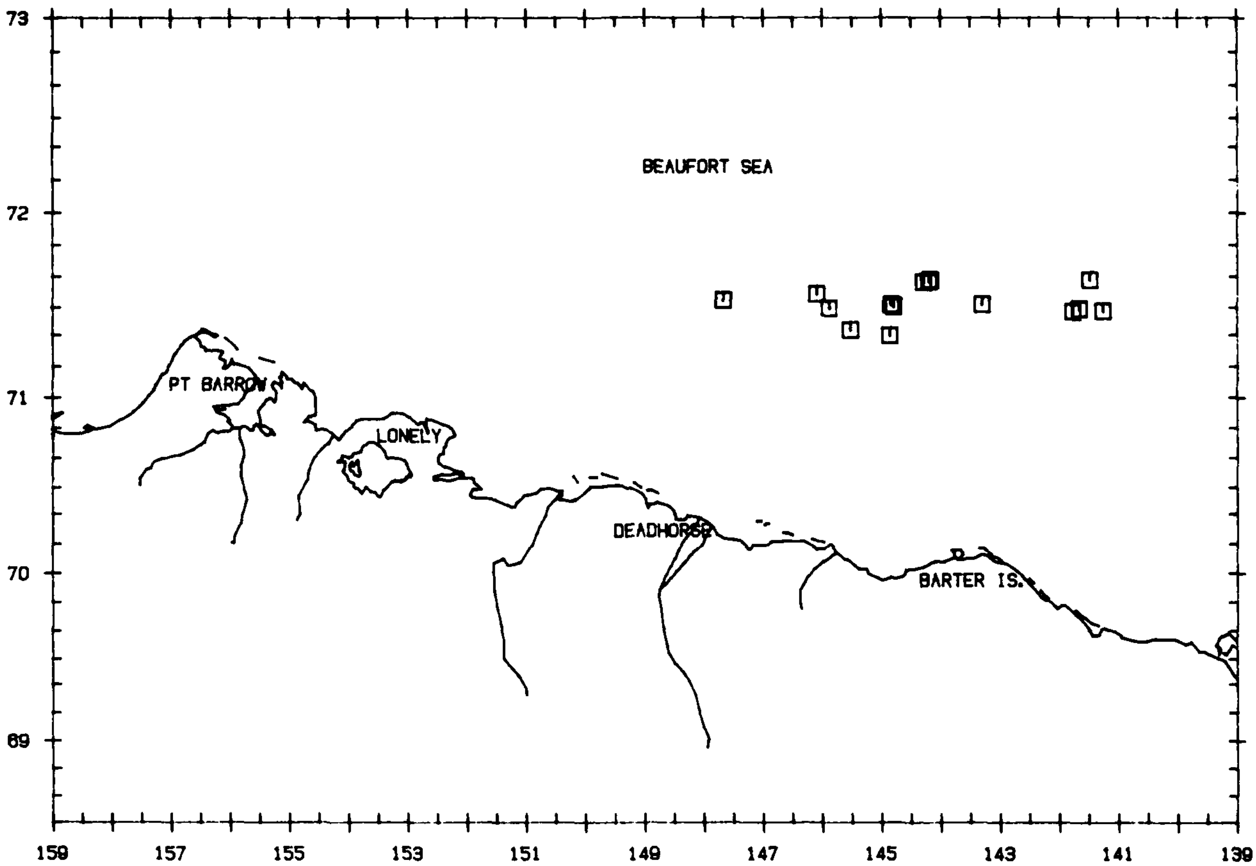


Figure 19. Distribution of 15 sightings of 16 bowhead whales, summer 1979-85 (June 1980).

(2) the coastal Chukchi Sea between Point Hope and Barrow where highest annual densities ranged from 0.261 to 1.47 whales/km^2.

The coastal waters south and east of Saint Lawrence Island supported relatively high densities of gray whales in 1982 (0.350 to 1.087 whales/km^2), the only year that the area was adequately surveyed to support the calculation of density estimates.

Gray whale distribution and highest densities correspond to areas where dense prey assemblages have been documented. The Chirikov Basin, in the north central Bering Sea, and coastal areas of Saint Lawrence Island have been described as primary feeding areas for gray whales (Rice and Wolman, 1971; Zimushko and Ivashin, 1979; Bogoslovskaya et al., 1981). Dense assemblages of benthic amphipods, dominated by the tube-building species <u>Ampelisca macrocephala</u> in the Chirikov Basin and by other more mobile species (eg., <u>Anonyx</u> and <u>Pontoporeia</u> spp.) in shallow waters near Saint Lawrence Island, have been reported (Stoker, 1981; Nerini and Oliver, 1983; Nerini, 1984; Oliver et al., 1984). The prey communities along the coastal Chukchi Sea are not as well documented (Stoker, 1981), but

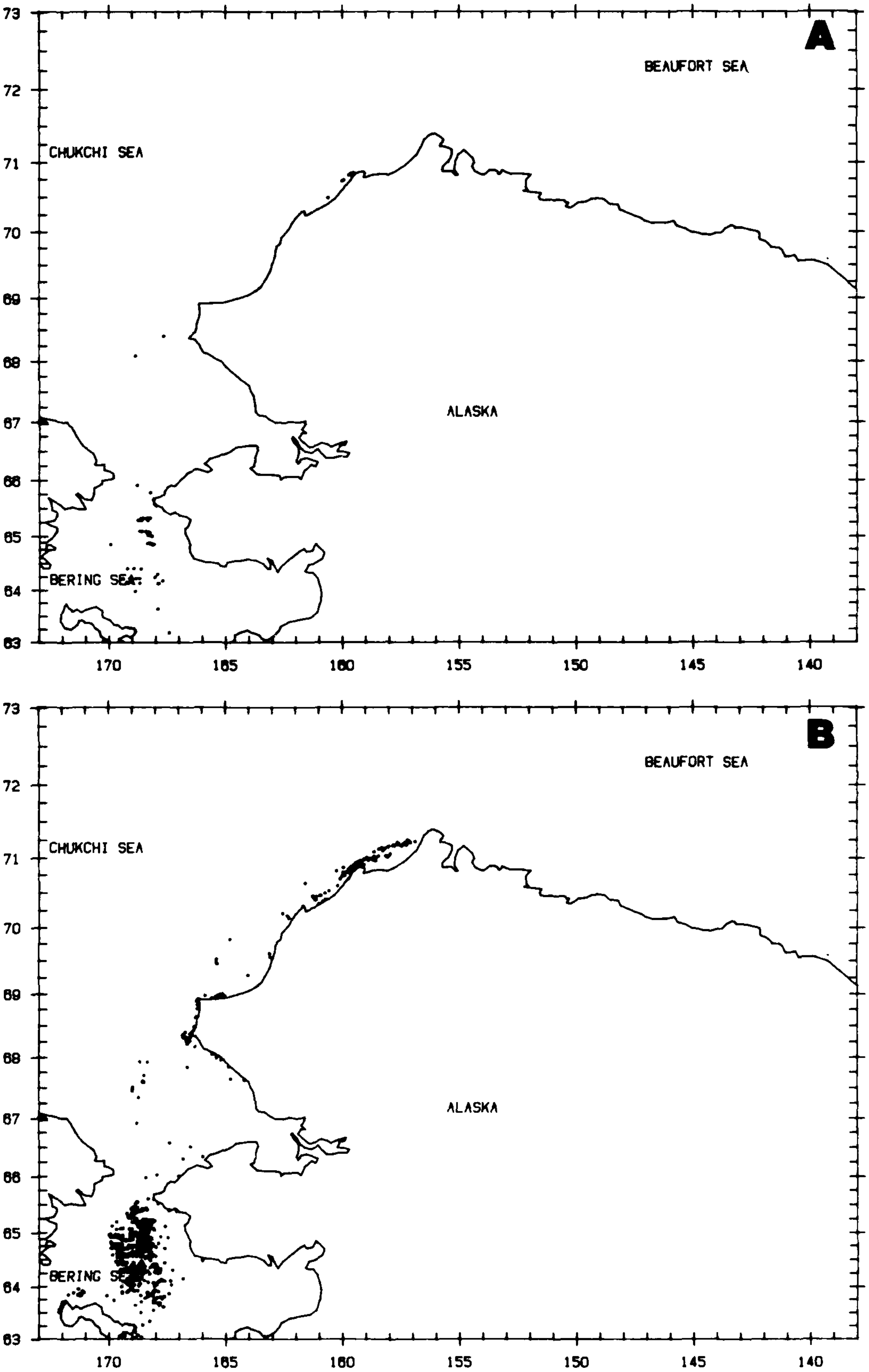


Figure 20. Distribution of 853 sightings of 2490 gray whales, summer 1980-85: 58 sightings of 152 whales, June (A); 795 sightings of 2338 whales, July (B).

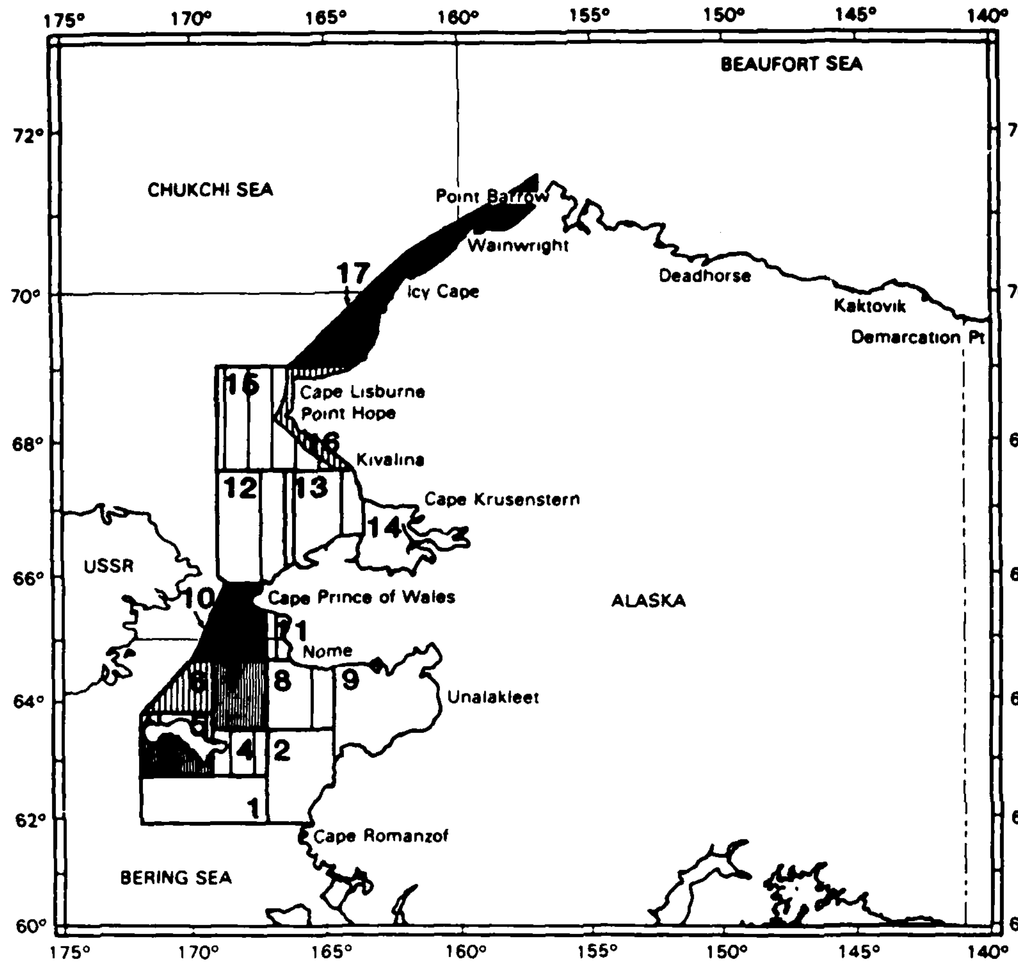


Figure 21. Highest annual gray whale densities/region, summer 1980-84. Shading varies from white (representing 0 density) to black (representing 0.495 whales/km^2). Densities presented here from Appendix B: Table B-2.

appear to consist of a variety of epibenthic and infaunal species. Benthic communities sampled south of Point Hope (water depth approx. 10-15 m), northeast of Cape Lisburne (water depth approx. 10 m) and southwest of Wainwright (water depth 25-30 m) were of three distinct types (J. Oliver, personal communication[8]). The community south of Point Hope consisted largely of swarms of epibenthic crustaceans (eg. mysids, amphipods, and shrimp) found above a course gravel bottom. The prey assemblage was found by divers sampling an area where four

Table 22. Annual summary of gray whale behavior, summer 1980-85.

	1980	1981	1982	1983	1984	1985	Total	(%)
BEHAVIOR:								
Swim/Dive	18	133	134	499	13	183	980	(39)
Feed	18	190	116	465	36	466	1291	(52)
Rest	0	3	32	57	0	22	114	(5)
Cow-Calf	12	12	38	2	2	34	100	(4)
Display	0	1	1	3	0	0	5	(0.2)
TOTAL	48	339	321	1026	51	705	2490	

gray whales appeared to be feeding and seemed to be very localized, as samples taken nearby but not directly under the feeding whales contained much lower prey densities. The samples collected northeast of Cape Lisburne were dominated by epibenthic isopods (Tectaceps spp.) that perch or crawl across the bottom. The stomach of a gray whale killed by killer whales (Orcinus orca) in this area was full of isopods. Southwest of Wainwright, infaunal amphipod communities similar to those in the Chirikov Basin and epibenthic cumaceans swarming 0.5 to 1 m off the bottom were sampled from areas where gray whales appeared to be feeding. In summary, gray whales feeding along the coastal Chukchi Sea probably forage opportunistically upon a mosaic of localized benthic communities consisting of both infaunal and epibenthic forms (J. Oliver, personal communication[8]). Whales feeding on epibenthic animals probably do not create mud plumes characteristic of whales foraging on infaunal species, thus their feeding may go unrecognized by aerial observers.

Habitat Relationships and Behavior

Gray whales were seen from 0.5 to 140 km from shore in water 7 m to 60 m deep ($\bar{x}$ = 36.7, 8.7 s.d.). Although 97 percent (n = 2415) of all gray whales were seen in open water, whales in the northeastern Chukchi Sea were sometimes found in ice coverage up to 30 percent.

More gray whales seen during summer surveys were feeding (52%, n = 1291) than any other single activity (Table 22). Other behaviors observed included

Table 23. Number of gray whale calves/total number of gray whales (C/GW) and estimated recruitment rate (GARR) by sea, summer 1980-85.

YEAR	Bering Sea C/GW (GARR)	Chukchi Sea C/GW (GARR)	TOTAL C/W (GARR)
1980*	--	6/46(0.13)	6/46(0.13)
1981	1/223(0.005)	5/116(0.04)	6/339(0.02)
1982	1/206(0.005)	18/115(0.15)	19/321(0.06)
1983	1/1005(0.001)	0/21(0)	1/1026(0.001)
1984	1/24(0.04)	0/27(0)	1/51(0.02)
1985	2/477(0.004)	15/228(0.07)	17/705(0.02)
TOTAL	6/1935(0.003)	44/553(0.08)	50/2488(0.02)

*ERRATUM: Ten sightings of 48 gray whales were recorded in error as 10 gray whales in Ljungblad et al. (1981, p. C-96 and 1985a, p. 94). Two of the 48 gray whales were in the Beaufort Sea.
-- = no surveys flown

swimming (39%, n = 980), resting (5%, n = 114), cow-calf associations (4%, n = 100) and displaying (< 1%, n = 5). Swimming direction was not consistently clustered about any heading, indicating little directed movement for summering whales.

Recruitment

Fifty gray whale calves have been seen in the northern Bering and eastern Chukchi Seas since 1980 (Table 23). Annual recruitment estimates (GARR) ranged from 0.1 to 13 percent with an overall GARR of 2.0 percent calculated over six seasons. This overall estimate is similar to the 2.5 percent annual recruitment rate (95% confidence limits = 0.4% to 4.6%) calculated by Reilly (1984), as reviewed by Cooke (1986).

Annual differences in GARR by sea were statistically significant ($X^2 = 128.3$, $p \leq 0.001$), and seemingly reflect a partial segregation of cow-calf groups on the northern range as suggested in Moore et al. (1986b). Of the 50 gray whale calves seen since 1980, six were seen among 1935 whales in the Bering Sea and 44 were among the 553 whales in the Chukchi Sea (Table 23). Resultant GARR ranged from 0.001 (1983) to 0.04 (1984) and averaged 0.003 in the northern Bering Sea. In the Chukchi Sea, GARR ranged from 0.0 (1983-84) to 0.15 (1982) and averaged 0.08.

Chapman (1984) noted that to derive an accurate GARR, given the existence of segregation, all components of the population must be sampled and then combined, weighed by the number of whales comprising each component. The GARR provided here was not corrected for such segregation, because the component(s) of the population sampled was not known with certainty for any year. Thus, the estimates presented in Table 23 represent only the observed ratio of calves to adults, and should be interpreted within the confines of the time periods and regions surveyed.

Relative abundance of gray whale calves (CPUE: calf per unit effort, unit effort = 1 hour survey time) was also significantly higher in the Chukchi Sea (0.39) than in the Bering Sea (0.05, $X^2 = 41.23$, $p < 0.001$; Table 24). Gray whale CPUE values were lowest in 1983 (0.04) and 1984 (0.05), when only one calf was seen per year, and in 1981 (0.06) when six calves were seen with far greater survey effort than in any other year. Relative abundance of gray whale calves was highest in 1980 (0.71), when six calves were seen between Pt. Hope and Cape Lisburne during a coastal survey. Overall, CPUE per block was highest in block 22 in 1980 (7.79), 1981 (0.51) and 1985 (1.55), in block 13 in 1982 (9.92) and in block 26 in 1983 (0.12) and 1984 (2.56). Highest CPUE per block for the Bering Sea was in block 25 (0.12). Highest CPUE per block in the Chukchi Sea, and for both seas across all years, was calculated for block 22 (1.27).

Cow-calf segregation has been reported for gray whales on the southern range (Jones and Swartz, 1984), and along their migration route (Rice and Wolman, 1971; Herzing and Mate, 1984; Poole, 1984). Harvest data also indicates that gray whales remain at least partially segregated and generally in coastal waters on the summer range (Blokhin, 1982, 1986; Votrogov and Bogoslovskaya, 1980). In addition, Maher (1960) reported the observation of "three calves with their mothers, and four to six other adults" near Cape Lisburne, and that gray whales taken near Barrow from 1954 to 1959 were either calves (n = 6), lactating females (n = 2), or juveniles (n = 2). Thus, it appears gray whales may maintain patterns of reproductive-class segregation throughout their range.

Although segregation of cow-calf groups on the feeding grounds may be expected as an extension of parturition and migratory segregation it is surprising that such groups, which enter the northern feeding grounds later, were found on the more northerly peripheral feeding area of the coastal Chukchi Sea rather than on the central feeding ground of the northern Bering Sea. Predator avoidance may be a causal factor in such distributional differences. Edwards (1983) reported that

Table 24. Relative abundance of gray whale calves (CPUE) = no. calves/hour of survey effort) by block, summer 1980-85.

Blocks	1980 Survey Hrs	1980 No. Calves	1980 CPUE	1981 Survey Hrs	1981 No. Calves	1981 CPUE	1982 Survey Hrs	1982 No. Calves	1982 CPUE
Chukchi Sea									
13	0.55	0	-	1.55	0	-	1.31	13	9.92
14	0.00	0	-	0.00	0	-	0.00	0	-
15	0.00	0	-	0.00	0	-	0.00	0	-
17	0.54	0	-	2.06	1	0.49	0.73	0	-
18	0.00	0	-	0.00	0	-	0.00	0	-
19	0.00	0	-	0.00	0	-	0.00	0	-
20	0.69	0	-	3.83	0	-	0.75	5	6.67
21	0.00	0	-	0.01	0	-	0.00	0	-
22	0.77	6	7.79	5.89	3	0.51	0.58	0	-
23	0.43	0	-	4.29	1	0.23	0.00	0	-
24	0.76	0	-	4.24	0	-	7.17	0	-
unblocked	3.11	0	-	17.59	0	-	2.65	0	-
Chukchi Sea Subtotal	6.90	6	0.87	39.76	5	0.13	13.19	18	1.36
Bering Sea									
25	0.70	0	-	13.24	1	0.08	6.44	0	-
26	0.00	0	-	2.26	0	-	5.52	0	-
28	0.21	0	-	13.01	0	-	8.55	1	0.11
29	0.00	0	-	5.94	0	-	0.00	0	-
unblocked	0.67	0	-	25.93	0	-	4.46	0	-
Bering Sea Subtotal	1.58	0	-	63.79	1	0.02	31.33	1	0.03
GRAND TOTAL	8.48	6	0.71	103.55	6	0.06	44.52	19	0.43

Blocks	1983 Survey Hrs	1983 No. Calves	1983 CPUE	1984 Survey Hrs	1984 No. Calves	1984 CPUE	1985 Survey Hrs	1985 No. Calves	1985 CPUE	TOTAL Survey Hrs	TOTAL No. Calves	TOTAL CPUE
Chukchi Sea												
13	0.42	0	-	5.93	0	-	9.77	7	0.72	19.83	20	1.01
14	0.00	[illegible]	-	3.12	0	-	3.25	0	-	6.37	0	-
15	0.00	0	-	0.00	0	-	3.22	0	-	3.22	0	-
17	0.78	0	-	3.07	0	-	3.81	2	0.52	10.99	3	0.27
18	0.00	0	-	0.62	0	-	2.90	0	-	3.52	0	-
19	0.00	0	-	0.00	0	-	0.33	0	-	0.33	0	-
20	0.94	0	-	0.95	0	-	2.85	0	-	10.01	5	0.50
21	0.00	0	-	0.00	0	-	1.91	0	-	1.92	0	-
22	0.39	0	-	0.31	0	-	3.88	6	1.55	11.82	15	1.27
23	0.00	0	-	0.39	0	-	0.00	0	-	5.16	1	0.19
24	0.18	0	-	0.52	0	-	0.17	0	-	13.04	0	-
unblocked	0.68	0	-	0.07	0	-	1.92	0	-	26.02	0	-
Chukchi Sea Subtotal	3.39	0	-	14.98	0	-	34.01	15	0.44	112.23	44	0.39
Bering Sea												
25	2.54	0	-	0.14	0	-	2.46	2	0.81	25.52	3	0.12
26	8.37	1	0.12	0.39	1	2.56	2.21	0	-	20.29	2	0.10
27	1.38	0	-	0.00	0	-	0.00	0	-	9.76	0	-
28	4.81	0	-	2.81	0	-	0.16	0	-	29.85	1	0.03
29	2.54	0	-	0.00	0	-	0.00	0	-	8.48	0	-
unblocked	2.46	0	-	0.03	0	-	0.00	0	-	33.60	0	-
Bering Sea Subtotal	22.60	1	0.04	3.37	1	0.30	4.83	2	0.41	127.50	6	0.05
GRAND TOTAL	25.99	1	0.04	18.35	1	0.05	38.84	17	0.44	239.73	50	0.21

cow-calf moose (Alces alces andersoni) pairs on Isle Royale, Michigan, were found on suboptimal peripheral feeding areas that were wolf-free, while solitary adults and yearling moose were found in the presence of wolves (Canis lupus) in areas of optimal forage. Killer whales (Orcinus orca) are known gray whale predators and have been observed chasing (Ljungblad and Moore, 1983) and killing (Braham et al., 1981) gray whales in the northern Bering Sea. Although killer whales have been reported in low numbers along the coastal Chukchi Sea (Frost et al., 1983), and a group of killer whales was observed to kill and partially devour a small gray whale near Cape Lisburne in July 1984 (J. Oliver, personal communication[8]), it is likely that gray whales encounter fewer killer whales there than in the Bering Sea (Dahlheim, 1981). Intraspecies competition may be a more likely causal factor in relegating cow-calf groups to coastal, or peripheral, feeding areas. An alternate gray whale feeding ground near Bamfield, British Columbia has been reported, and observations made there on the respiration pattern of a "small" (6 m) feeding whale (Oliver et al., 1984). Because killer whales are common in waters near British Columbia (Dahlheim, 1981), intraspecific competitive factors rather than predator avoidance might be important correlations in finding young gray whales there. In summary, gray whale cows with calves may be excluded from, or prefer to stay away from, dense aggregations of adult and sub-adult whales on the central Bering Sea feeding ground and are more often found along the coastal Chukchi Sea.

FALL (August - November)

The primary objectives of fall aerial surveys have been to determine the distribution and timing of the bowhead whale migration, to derive relative and absolute abundance estimates in or near proposed or existing federal lease areas, and to describe bowhead whale general behavior and record underwater sound production.

Survey Effort and Conditions Summary

A total of 1509.8 survey hours has been flown in the fall since 1979, with 88 percent (1325.9 h) of this effort in the Beaufort Sea, 9 percent (134.7 h) in the Chukchi Sea, and 3 percent (49.2 h) in the northern Bering Sea (Table 25). There has been considerable variability in survey effort over the years. There was little effort flown in August 1979-81 due to aircraft unavailability and/or its diversion to support other MMS-funded projects. Although surveys were flown each year in

Table 25. Summary of flight effort (hours:minutes) by sea, fall 1979-85.

	1979	1980	1981	1982	1983	1984	1985	Total (%)
Bering Sea	0	33:45	14:43	0	0:42	0	0	49:10(3)
Chukchi Sea	0:48	14:30	11:24	18:56	42:41	31:19	15:06	134:44(9)
Beaufort Sea	171:06	156:49	144:19	204:44	236:29	214:47	197:43	1325:57(88)
TOTAL	171:54	205:04*	170:26	223:40	279:52	246:06	212:49	1509:51

*includes 21:38 flown in November 1980

September, areas covered varied annually. For example, in 1979 and 1980 transect surveys were flown primarily near-shore in oil lease areas (blocks 1 and 3), with search surveys flown in blocks 4 and 5. In 1981, September survey efforts were divided between transect surveys in blocks 1 and 3, and behavioral observation surveys (usually in blocks 4, 5, 6 and 7) conducted in an attempt to document significant differences in bowhead whale behaviors when whales were near active geophysical vessels (Fraker et al., 1985). In 1982-85, September transect surveys were generally conducted in blocks 1 through 9 in early September, and in blocks 1 through 14, 17 and 18 from mid-September through mid-October. The termination of fall survey effort in the Beaufort Sea has occurred from 15 to 31 October. In 1980, the last survey in the Beaufort Sea was flown on 25 October, but surveys in the northern Bering Sea were continued through 4 November.

Fall ice conditions varied annually, but may be generally regarded as predominantly heavy (70% to 90%), or light (0 to 30%) coverage. In light ice years (1979, 1981, 1982, 1984) ice coverage in the Alaskan Beaufort Sea was relatively heavy through early August, became and remained light from mid-August through September, with freeze up commencing in early October. In heavy ice years (1980, 1983) ice coverage remained heavy throughout the fall season. Ice conditions in 1985 did not conform completely to this paradigm, however, as coverage in early and late September was $\leq$60% in some areas, resulting in average ice coverage for the 1985 season that was intermediate (30% $\leq$ ice $\leq$ 70%) to previous years.

Table 26. Bimonthly summary of bowhead whale sightings (number of sightings/number of whales), fall 1979-85.

YEAR	AUGUST		SEPTEMBER		OCTOBER		TOTAL
	1-15	16-31	1-15	16-30	1-15	16-31	
1979	(0)	(4/7)	2/2	28/58	60/86	27/44	121/197
1980	(0)	(0)	9/12	15/22	8/12	(0)	32/46
1981	(0)	(1/2)	47/63	144/169	43/54	--	235/288
1982	57/108	22/37	25/54	90/247	27/43	(1/1)	222/490
1983	25/49	7/10	19/24	41/54	17/24	(7/11)	116/172
1984	2/3	11/18	12/17	64/243	52/77	(13/22)	154/380
1985	8/9	3/3	13/34	18/33	34/59	(1/1)	77/139
TOTAL	(92/169)	(48/77)	127/206	400/826	241/355	(49/79)	957/1712

(surveys not conducted over entire period)

-- = no surveys conducted

Sea states encountered on fall surveys ranged from 00 to 06, with 01 to 03 conditions the most common. Sea states during heavy ice years generally ranged from 00 to 02 due to the dampening influence of the ice coverage. Fog often caused surveys to be truncated or aborted in August and September when ice conditions changed daily. In October, high winds often curtailed survey efforts.

BOWHEAD WHALE

Distribution, Relative Abundance, and Density

There were 957 sightings of 1712 bowheads made over seven fall seasons (Table 26, Figure 22). The distribution of 139 bowheads seen in 1985 (Figure 11) was similar to, but not comprehensive of, past years.

In August, bowheads have been seen from 0.5 to 180 km from shore between 138°W to 147°W (Figure 22A), with annual variation as follows:

- o In 1979, seven whales were seen between 143°W and 144°30'W, offshore to 70°41'N
- o In 1981, two whales were seen near 138°W, at 69°33'N

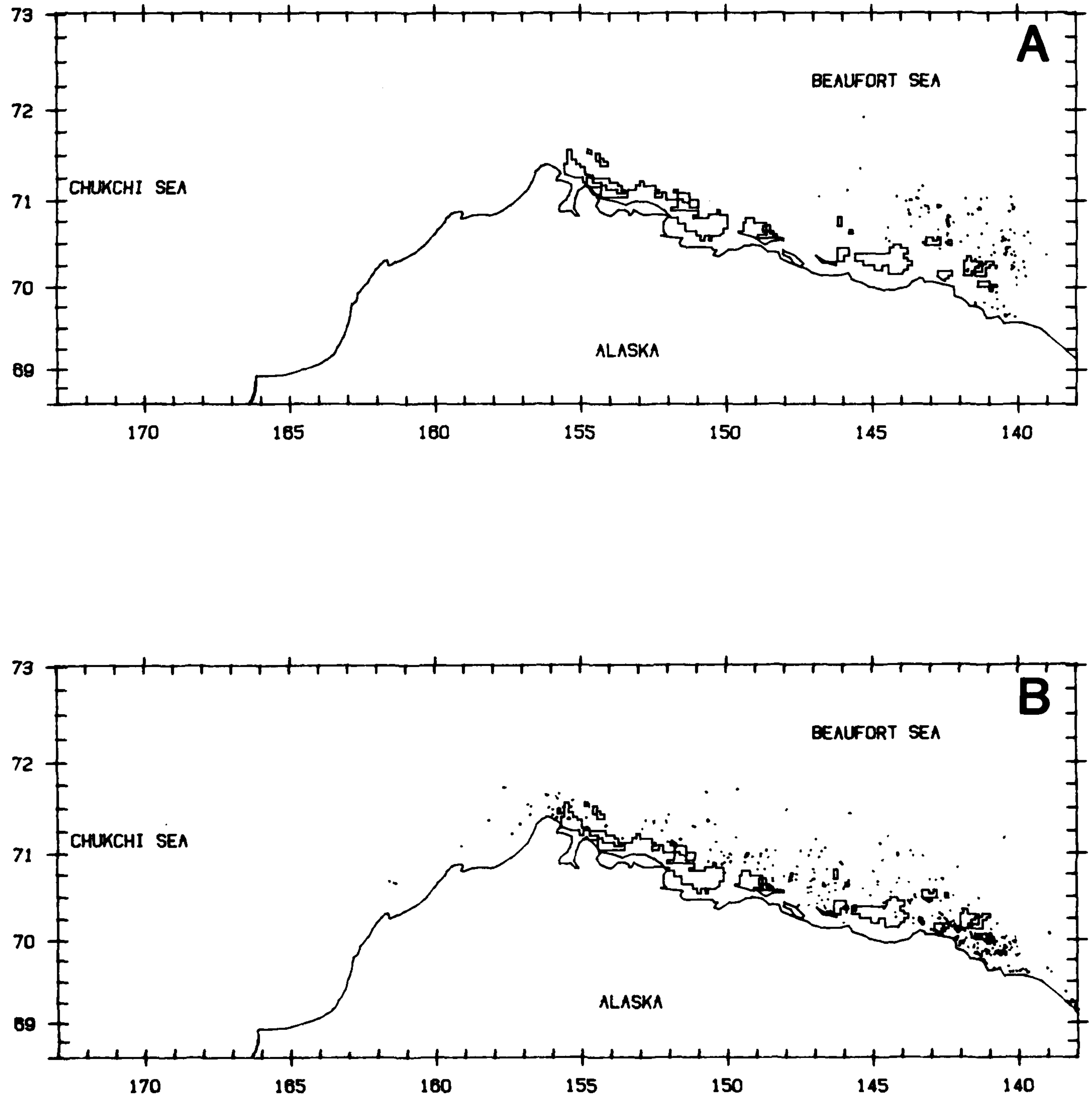


Figure 22. Distribution of 957 sightings of 1712 bowheads plotted by month, fall 1979-85: 140 sightings of 246 whales, August (A); 527 sightings of 1032 whales, September (B)

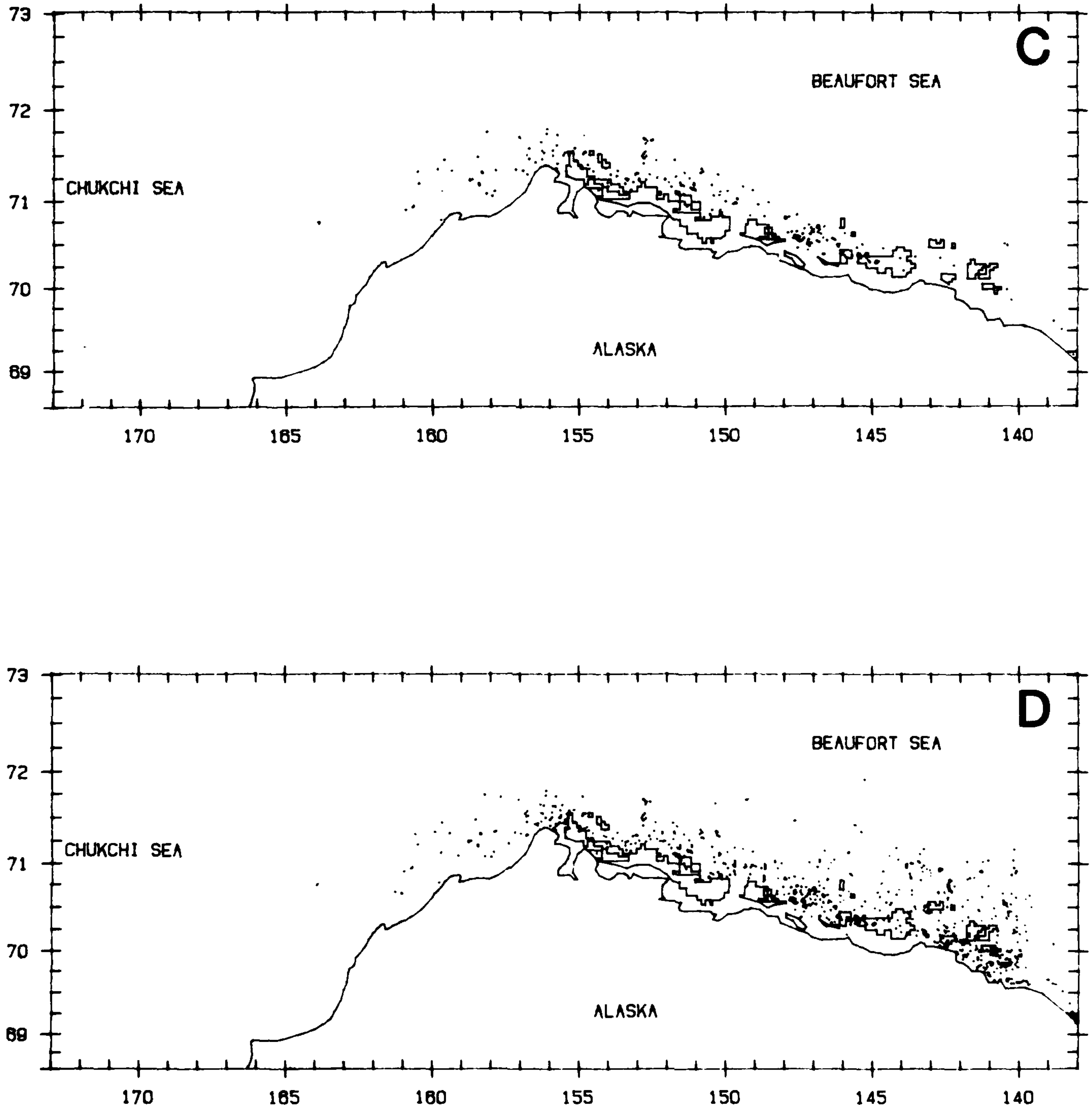


Figure 22 (contd). 290 sightings of 434 whales, October (C); all sightings (D)). Outlined areas depict OCS oil and gas lease areas within the Beaufort Sea Planning Area of the Alaskan Beaufort Sea.

- o In 1982, 145 whales were seen between 139°33'W and 145°49'W, offshore to 71°54'N
- o In 1983, 59 whales were seen between 139°38'W and 146°48'W, offshore to 71°03'N
- o In 1984, 21 whales were seen between 139°W and 141°26'W, offshore to 70°23'N
- o In 1985, 12 whales were seen from 140°W to 141°56'W, offshore to 70°31'N

As previously mentioned there was little August survey effort in the Beaufort Sea in 1979-81, therefore, bowhead distribution and number are probably under-represented for those years. In 1982-85, August surveys were routinely flown in blocks 1 through 9, and bowheads were seen in all blocks except 1, 3, 4, and 8. Many more whales were seen, and their distribution extended further north and west, in 1982-83 than in 1984-85. In all years since 1982, August bowhead distribution has coincided with only the easternmost boundaries of OCS oil and gas lease areas; generally whales have been seen north, east, or shoreward of lease areas (Figure 22A).

In September, bowheads have been seen across the Alaskan Beaufort Sea generally along the shelf break and into the northeastern Chukchi Sea (Figure 22B), with annual variation as follows:

- o In 1979, 60 whales were seen between 140°58'W and 146°33'W, offshore to 70°38'N
- o In 1980, 34 whales were seen between 138°45'W and 149°43'W, offshore to 70°53'N
- o In 1981, 232 whales were seen between 138°16'W and 146°27'W, offshore to 70°23'N
- o In 1982, 301 whales were seen between 139°47'W and 155°37'W, offshore to 71°39'N
- o In 1983, 78 whales were seen between 140°12'W and 161°14'W, offshore to 71°41'N
- o In 1984, 260 whales were seen between 137°58'W and 157°39'W, offshore to 71°43'N
- o In 1985, 67 whales were seen between 139°01'W and 146°41'W, offshore to 70°40'N

AD-A172 753 AERIAL SURVEYS OF ENDANGERED WHALES IN THE NORTHERN BERING EASTERN CHUKCH..(U) NAVAL OCEAN SYSTEMS CENTER SAN DIEGO CA D K LJUNGBLAD ET AL. AUG 86 NOSC/TR-1111

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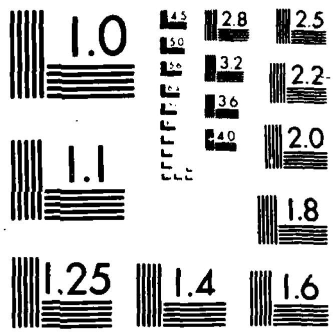
1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

The 1979-81 September survey effort was directed to blocks 1 through 6, and whales were seen in all blocks except 2 and 3. In 1982-85, September surveys were routinely flown in blocks 1 through 13, and occasionally in blocks 14 and 17. Notably, September bowhead distribution extended offshore to about 71°40'N in all years that survey coverage was expanded to include blocks 7 through 13, except in 1985. The 1985 distribution was similar to that observed in 1979-81 when surveys were generally confined to near-shore blocks. In all years, September bowhead distribution has overlapped the boundaries of OCS oil and gas lease areas between 141°W and 150°W, been generally north of the lease areas between 150°W and 155°W, and overlapped the northwesternmost OCS lease areas (Figure 22B).

In October, whales have been found along the shelf break in the Beaufort Sea, with relatively more whales seen west of 150°W and in the northeastern Chukchi Sea than in September (Figure 22C). Annual variation in October bowhead distribution was as follows:

- In 1979, 130 whales were seen between 144°45'W and 155°40'W, offshore to 71°32'N
- In 1980, 12 whales were seen between 144°02'W and 153°10'W, offshore to 71°18'N
- In 1981, 54 whales were seen between 143°36'W and 153°24'W, offshore to 71°16'N
- In 1982, 44 whales were seen between 138°52'W and 160°34'W, offshore to 71°45'N
- In 1983, 35 whales were seen between 140°24'W and 163°54'W, offshore to 71°44'N
- In 1984, 99 whales were seen between 137°51'W and 159°42'W, offshore to 71°48'N
- In 1985, 60 whales were seen between 147°21'W and 160°29'W, offshore to 71°43'N

As in September, survey efforts in October were expanded to offshore Beaufort Sea, and coastal Chukchi Sea survey blocks (i.e., generally blocks 7 to 18) after 1981. In all years, October coverage included blocks 1 through 6, 11 and 12. Bowheads were seen in all Beaufort Sea survey blocks except 8, 9 and 10; in the Chukchi Sea, whales were seen in blocks 13, 14, 17 and 18. In all years, October bowhead distribution overlapped OCS lease area boundaries east of 150°W, and west of 154°W (Figure 22C).

The annual variation of bowhead relative abundance (WPUE) in the survey blocks (Table 27) reflects the patterns of survey effort and bowhead distribution discussed above. Highest seasonal WPUE was calculated for block 5 in all years except 1984 and 1985. In 1984, highest WPUE was calculated for block 12 where large aggregations of whales were seen feeding that year (Ljungblad et al., 1986a). Highest WPUE in 1985 was also associated with a group of feeding bowheads in block 11. An annual review of the shifts in highest monthly WPUE may be summarized as follows:

- In 1979, bowhead relative abundance was highest in block 6 in August, block 5 in September, and block 3 in October
- In 1980, there were no bowheads seen in August, relative abundance was highest in block 5 in September, and block 2 in October
- In 1981, bowheads were not seen in August, highest abundance was calculated for block 5 in September, and block 4 in October
- In 1982, bowhead relative abundance was highest in block 7 in August, block 5 in September, and block 13 in October
- In 1983, bowhead relative abundance was highest in block 5 in August, block 17 in September, and block 7 in October
- In 1984, bowhead relative abundance was highest in block 5 in August, block 12 in September, and block 11 in October
- In 1985, bowhead relative abundance was highest in block 5 in August, block 4 in September, and block 11 in October

Overall (1979-85), highest abundance indices were calculated for block 7 in August, block 12 in September and block 11 in October. These patterns of change in bowhead distribution and relative abundance over time indicate that whales are generally found somewhat offshore in the eastern Alaskan Beaufort Sea in August, in coastal blocks across the Alaskan Beaufort and northeastern Chukchi Sea in September, and somewhat offshore in the central and western Alaskan Beaufort Sea, and in coastal Chukchi Sea survey blocks in October. Differences in abundance indices calculated for each survey block between years reflect the annual variation in the distribution and timing of whale movements during the migration.

Table 27. Monthly and seasonal relative abundance (WPUE) of bowhead whales by survey block, fall 1979-85. **Bold** indicates survey blocks with the highest monthly and seasonal WPUE. WPUE = no. whales/hours of survey effort.

1979

	August			September			October			Total		
Block	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE
1	19.25	0	-	24.33	2	0.08	55.76	88	1.58	99.34	90	0.91
2	2.15	0	-	2.50	0	-	3.17	0	-	7.82	0	-
3	0.00	0	-	0.65	0	-	**7.36**	**27**	**3.67**	8.01	27	3.37
4	11.63	0	-	11.39	1	0.09	4.25	10	2.35	27.27	11	0.40
5	0.00	0	-	**5.26**	**53**	**10.08**	0.00	0	-	**5.26**	**53**	**10.08**
6	**5.13**	**7**	**1.36**	5.47	4	0.73	1.02	0	-	11.62	11	0.95
7	0.00	0	-	1.36	0	-	0.00	0	-	1.36	0	-
8	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
9	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
10	0.36	0	-	0.00	0	-	0.00	0	-	0.36	0	-
11	0.00	0	-	0.00	0	-	1.29	0	-	1.29	0	-
12	0.00	0	-	0.42	0	-	7.14	5	0.70	7.56	5	0.66
13	0.00	0	-	0.00	0	-	0.19	0	-	0.19	0	-
14	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
15	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
16	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
17	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
18	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
19	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
20	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
21	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
22	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
23	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
24	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
25	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
26	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
27	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
28	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
29	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
Block Total	38.52	7	0.18	51.38	60	1.17	80.18	130	1.62	170.08	197	1.16
Total Canada	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
Total Unblocked	0.00	0	-	0.00	0	-	1.82	0	-	1.82	0	-
GRAND TOTAL	38.52	7	0.18	51.38	60	1.17	82.00	130	1.59	171.90	197	1.15

1980

	August			September			October			Total		
Block	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE
1	7.48	0	-	38.98	15	0.38	19.55	2	0.10	66.01	17	0.26
2	0.36	0	-	1.16	0	-	**1.69**	**2**	**1.18**	3.21	2	0.62
3	7.00	0	-	12.41	0	-	20.12	7	0.35	39.53	7	0.18
4	1.46	0	-	10.75	5	0.47	3.42	1	0.29	15.63	6	0.38
5	2.98	0	-	**10.01**	**10**	**0.99**	2.04	0	-	**15.03**	**10**	**0.67**
6	0.00	0	-	1.06	0	-	0.11	0	-	1.17	0	-
7	0.00	0	-	0.80	0	-	0.00	0	-	0.80	0	-
8	0.00	0	-	0.26	0	-	0.00	0	-	0.26	0	-
9	0.00	0	-	0.29	0	-	0.00	0	-	0.29	0	-
10	0.00	0	-	0.57	0	-	0.18	0	-	0.75	0	-
11	0.51	0	-	0.12	0	-	1.67	0	-	2.30	0	-
12	0.00	0	-	0.00	0	-	1.94	0	-	1.94	0	-
13	0.00	0	-	0.00	0	-	0.50	0	-	0.50	0	-
14	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
15	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
16	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
17	0.00	0	-	0.00	0	-	0.58	0	-	0.58	0	-
18	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
19	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
20	0.00	0	-	0.00	0	-	0.69	0	-	0.69	0	-
21	0.00	0	-	0.00	0	-	1.85	0	-	1.85	0	-
22	0.00	0	-	0.00	0	-	3.82	0	-	3.82	0	-
23	0.00	0	-	0.00	0	-	2.32	0	-	2.32	0	-
24	0.00	0	-	0.00	0	-	3.59	0	-	3.59	0	-
25	0.00	0	-	0.00	0	-	4.25	0	-	4.25	0	-
26	0.00	0	-	0.00	0	-	5.83	0	-	5.83	0	-
28	0.00	0	-	0.00	0	-	2.09	0	-	2.09	0	-
29	0.00	0	-	0.00	0	-	0.03	0	-	0.03	0	-
Block Total	19.79	0	-	76.41	30	0.39	76.27	12	0.16	172.47	42	0.24
Total Canada	0.67	0	-	8.58	4	0.47	0.65	0	-	9.90	4	0.40
Total Unblocked	0.00	0	-	0.00	0	-	1.07	0	-	1.07	0	-
GRAND TOTAL	20.46	0	-	84.99	34	0.40	77.99	12	0.15	183.44	46	0.25

Table 27 (contd).

1981

	August			September			October			Total		
Block	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE
1	6.65	0	-	23.24	5	0.22	19.01	17	0.89	48.90	22	0.45
2	0.36	0	-	0.48	0	-	0.30	0	-	1.14	0	-
3	2.98	0	-	5.34	0	-	13.34	7	0.52	21.66	7	0.32
4	4.22	0	-	15.67	**96**	6.13	**7.11**	**30**	**4.22**	27.00	126	4.67
5	1.94	0	-	**30.98**	**130**	**6.20**	2.98	0	-	**25.90**	**130**	**5.02**
6	0.00	0	-	1.44	0	-	1.46	0	-	2.90	0	-
7	0.54	0	-	1.67	0	-	1.15	0	-	3.36	0	-
8	0.00	0	-	1.31	0	-	0.00	0	-	1.31	0	-
9	0.00	0	-	0.12	0	-	0.00	0	-	0.12	0	-
10	0.52	0	-	0.00	0	-	0.00	0	-	0.52	0	-
11	0.39	0	-	0.03	0	-	0.28	0	-	0.70	0	-
12	1.86	C	-	0.00	0	-	0.37	0	-	2.23	0	-
13	1.14	0	-	0.00	0	-	0.00	0	-	1.14	0	-
14	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
15	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
16	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
17	1.17	0	-	0.00	0	-	0.00	0	-	1.17	0	-
18	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
19	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
20	2.08	0	-	0.00	0	-	0.00	0	-	2.08	0	-
21	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
22	0.52	0	-	0.00	0	-	0.00	0	-	0.52	0	-
23	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
24	2.39	0	-	0.00	0	-	0.00	0	-	2.39	0	-
25	3.61	0	-	0.00	0	-	0.00	0	-	3.61	0	-
26	0.91	0	-	0.00	0	-	0.00	0	-	0.91	0	-
27	0.63	0	-	0.00	0	-	0.00	0	-	0.63	0	-
28	3.47	0	-	0.00	0	-	0.00	0	-	3.47	0	-
29	3.42	0	-	0.00	0	-	0.00	0	-	3.42	0	-
Block Total	38.80	0	-	70.28	231	3.29	46.00	54	-	155.08	285	1.84
Total Canada	3.27	2	0.61	3.17	1	0.32	0.00	0	-	6.44	3	0.47
Total Unblocked	8.87	0	-	0.04	0	-	0.00	0	-	8.91	0	-
GRAND TOTAL	50.94	2	0.04	73.49	232	3.16	46.00	54	1.17	170.43	288	1.69

1982

	August			September			October			Total		
Block	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE
1	9.99	0	-	13.76	94	6.83	5.35	1	0.19	29.10	95	3.26
2	3.70	0	-	2.22	3	1.35	1.21	0	-	7.13	3	0.42
3	0.00	0	-	14.53	13	0.89	3.63	9	2.48	18.16	22	1.21
4	14.27	0	-	8.58	8	0.93	4.02	0	-	26.87	8	0.30
5	19.14	16	0.84	**14.07**	**159**	**11.30**	4.27	3	0.70	**37.48**	**178**	**4.75**
6	15.22	43	2.83	5.38	0	-	1.83	0	-	22.43	43	1.92
7	**12.35**	**75**	**6.07**	3.86	0	-	0.00	0	-	16.21	75	4.63
8	4.90	0	-	1.55	0	-	0.59	0	-	7.04	0	-
9	3.73	2	0.54	3.13	4	1.28	0.48	0	-	7.34	6	0.82
10	0.54	0	-	0.00	0	-	0.43	0	-	0.97	0	-
11	0.00	0	-	4.56	0	-	5.35	1	0.19	9.91	1	0.10
12	0.00	0	-	4.17	2	0.48	8.01	15	1.87	12.18	17	1.40
13	0.00	0	-	3.58	0	-	**4.34**	**12**	**2.76**	7.92	12	1.52
14	0.00	0	-	0.00	0	-	2.46	1	0.41	2.46	1	0.41
15	0.00	0	-	0.00	0	-	0.12	0	-	0.12	0	-
16	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
17	0.00	0	-	0.00	0	-	3.81	0	-	3.81	0	-
18	0.00	0	-	0.00	0	-	2.00	0	-	2.00	0	-
19	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
20	0.00	0	-	0.00	0	-	3.40	0	-	3.40	0	-
21	0.00	0	-	0.00	0	-	1.35	0	-	1.35	0	-
22	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
23	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
24	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
25	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
26	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
27	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
28	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
29	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
Block Total	83.84	136	1.62	79.39	283	3.56	52.65	42	0.80	215.88	461	2.14
Total Canada	1.80	9	5.00	0.37	18	48.65	4.39	2	0.46	6.56	29	4.42
Total Unblocked	0.36	0	-	0.18	0	-	0.70	0	-	1.24	0	-
GRAND TOTAL	86.00	145	1.69	79.94	301	3.77	57.74	44	0.76	223.68	490	2.19

Table 27 (contd).

1983

	August			September			October			Total		
Block	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE
1	9.82	0	-	17.99	2	0.11	5.77	0	-	33.58	2	0.06
2	2.91	1	0.34	10.34	9	0.87	1.54	0	-	14.79	10	0.68
3	11.96	0	-	13.22	8	0.61	6.13	3	0.49	31.31	11	0.35
4	7.08	0	-	3.33	0	-	3.65	0	-	14.06	0	-
5	**12.05**	**38**	**3.15**	4.91	0	-	1.11	0	-	**18.07**	**38**	**2.10**
6	6.28	0	-	11.29	17	1.51	3.70	1	0.27	21.27	18	0.85
7	13.92	17	1.22	4.20	8	1.90	**2.30**	**5**	**2.17**	20.42	30	1.47
8	4.92	0	-	3.34	0	-	0.00	0	-	8.26	0	-
9	4.45	0	-	2.78	1	0.36	0.00	0	-	7.23	1	0.14
10	5.22	0	-	9.34	2	0.21	0.79	0	-	15.35	2	0.13
11	2.57	0	-	13.10	7	0.53	5.81	0	-	21.48	7	0.33
12	5.49	0	-	10.69	18	1.68	10.74	8	0.74	26.92	26	0.97
13	0.00	0	-	3.28	3	0.91	8.88	13	1.46	12.16	16	1.32
14	0.00	0	-	0.87	0	-	3.95	0	-	4.82	0	-
15	0.00	0	-	0.00	0	-	3.73	0	-	3.73	0	-
16	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
17	0.00	0	-	**0.96**	**3**	**3.12**	4.29	3	0.70	5.25	6	1.14
18	0.00	0	-	0.00	0	-	4.61	2	0.43	4.61	2	0.43
19	0.00	0	-	0.00	0	-	0.37	0	-	0.37	0	-
20	0.00	0	-	0.00	0	-	2.97	0	-	2.97	0	-
21	0.00	0	-	0.00	0	-	1.73	0	-	1.73	0	-
22	0.00	0	-	0.00	0	-	3.60	0	-	3.60	0	-
23	0.00	0	-	0.00	0	-	0.59	0	-	0.59	0	-
24	0.00	0	-	0.00	0	-	0.34	0	-	0.34	0	-
25	0.00	0	-	0.00	0	-	0.51	0	-	0.51	0	-
26	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
27	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
28	0.00	0	-	0.00	0	-	0.18	0	-	0.18	0	-
29	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
Block Total	86.67	56	0.65	109.64	76	0.69	77.29	35	0.45	273.60	169	0.62
Total Canada	0.81	3	3.70	0.00	0	-	0.00	0	-	0.81	3	3.70
Total Unblocked	0.60	0	-	1.27	0	-	3.58	0	-	5.45	0	-
GRAND TOTAL	88.08	59	0.67	110.91	76	0.69	80.87	35	0.43	279.86	172	0.61

1984

	August			September			October			Total		
Block	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE	Hrs	BH	WPUE
1	9.46	0	-	16.98	10	0.59	13.93	4	0.29	40.37	14	0.35
2	1.88	0	-	3.80	4	1.05	3.81	1	0.26	9.49	5	0.53
3	3.21	0	-	10.94	2	0.18	17.68	22	1.24	31.83	24	0.75
4	12.60	0	-	5.58	15	2.69	1.85	0	-	20.03	15	0.75
5	**16.45**	**19**	**1.16**	8.77	28	3.19	2.91	4	1.37	28.13	51	1.81
6	8.11	0	-	4.64	9	1.94	2.04	0	-	14.79	9	0.61
7	9.73	0	-	3.73	0	-	0.00	0	-	13.46	0	-
8	2.99	0	-	1.53	0	-	0.00	0	-	4.52	0	-
9	2.92	0	-	3.33	0	-	0.00	0	-	6.25	0	-
10	0.06	0	-	4.53	0	-	0.10	0	-	4.69	0	-
11	2.30	0	-	4.17	0	-	**5.57**	**17**	**3.05**	12.04	17	1.41
12	1.01	0	-	**5.63**	**148**	**26.29**	15.58	37	2.37	**22.22**	**185**	**8.33**
13	5.61	0	-	4.76	2	0.42	5.77	5	0.87	16.14	7	0.43
14	2.19	0	-	2.79	0	-	0.11	0	-	5.09	0	-
15	2.14	0	-	0.00	0	-	0.00	0	-	2.14	0	-
16	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
17	1.05	0	-	0.75	0	-	1.90	0	-	3.70	0	-
18	0.33	0	-	0.00	0	-	0.00	0	-	0.33	0	-
19	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
20	3.08	0	-	0.00	0	-	0.00	0	-	3.08	0	-
21	0.41	0	-	0.00	0	-	0.00	0	-	0.41	0	-
22	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
23	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
24	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
25	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
26	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
27	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
28	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
29	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
Block Total	85.53	19	0.22	81.93	218	2.66	71.25	90	1.26	238.71	327	1.37
Total Canada	1.23	2	1.63	2.47	42	17.00	2.43	9	3.70	6.13	53	8.65
Total Unblocked	0.22	0	-	0.37	0	-	0.66	0	-	1.25	0	-
GRAND TOTAL	86.99	21	0.24	84.77	260	3.07	74.34	99	1.33	246.09	380	1.54

Table 27 (contd).

1985

Block	August Hrs	August BH	August WPUE	September Hrs	September BH	September WPUE	October Hrs	October BH	October WPUE	Total Hrs	Total BH	Total WPUE
1	10.67	0	-	13.04	7	0.54	7.97	18	2.26	31.68	25	0.79
2	1.67	0	-	4.16	0	-	1.75	0	-	7.58	0	-
3	0.00	0	-	4.90	0	-	12.38	5	0.40	17.28	5	0.29
4	16.75	0	-	**10.39**	**23**	**2.21**	6.22	0	-	33.36	23	0.69
5	**17.52**	**11**	**0.63**	10.89	19	1.74	9.16	0	-	37.57	30	0.80
6	7.31	0	-	7.78	3	0.39	2.09	0	-	17.18	3	0.17
7	8.70	1	0.18	7.08	0	-	2.08	0	-	17.86	1	0.06
8	3.01	0	-	5.33	0	-	0.06	0	-	8.40	0	-
9	0.32	0	-	0.36	0	-	0.00	0	-	0.68	0	-
10	0.16	0	-	0.18	0	-	0.25	0	-	0.59	0	-
11	0.00	0	-	0.19	0	-	**3.00**	**27**	**9.00**	**3.19**	**27**	**8.46**
12	0.00	0	-	3.08	0	-	13.25	7	0.53	16.33	7	0.43
13	0.00	0	-	0.00	0	-	6.40	2	0.31	6.40	2	0.31
14	0.00	0	-	0.00	0	-	2.09	1	0.48	2.09	1	0.48
15	0.00	0	-	0.00	0	-	1.00	0	-	1.00	0	-
16	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
17	0.00	0	-	0.00	0	-	2.69	0	-	2.69	0	-
18	0.00	0	-	0.00	0	-	2.90	0	-	2.90	0	-
19	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
20	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
21	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
22	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
23	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
24	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
25	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
26	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
27	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
28	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
29	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
Block Total	66.11	12	0.18	67.38	52	0.77	73.29	60	0.82	206.78	124	0.60
Total Canada	0.91	0	-	2.30	15	6.52	1.96	0	-	5.17	15	2.90
Total Unblocked	0.00	0	-	0.09	0	-	0.78	0	-	0.87	0	-
GRAND TOTAL	67.02	12	0.18	69.77	67	0.96	76.03	60	0.79	212.82	139	0.65

TOTAL

Block	August Hrs	August BH	August WPUE	September Hrs	September BH	September WPUE	October Hrs	October BH	October WPUE	Total Hrs	Total BH	Total WPUE
1	73.32	0	-	148.32	135	0.91	127.34	130	1.02	348.98	265	0.76
2	13.03	1	0.08	24.66	16	0.65	13.47	3	0.22	51.16	20	0.39
3	25.15	0	-	61.99	23	0.37	80.64	80	0.99	167.78	103	0.61
4	68.01	0	-	65.69	148	2.25	30.52	41	1.34	164.22	189	1.15
5	70.08	84	1.20	74.89	399	5.33	22.47	7	0.31	**167.44**	**490**	**2.93**
6	42.05	50	1.19	37.06	33	0.89	12.25	1	0.08	91.36	84	0.92
7	**45.24**	**93**	**2.06**	22.70	8	0.35	5.53	5	0.90	73.47	106	1.44
8	15.82	0	-	13.32	0	-	0.65	0	-	29.79	0	-
9	11.42	2	0.18	10.01	5	0.50	0.48	0	-	21.91	7	0.32
10	6.86	0	-	14.62	2	0.14	1.75	0	-	23.23	2	0.09
11	5.77	0	-	22.17	7	0.32	**22.97**	**45**	**1.96**	50.91	52	1.02
12	8.36	0	-	**23.99**	**168**	**7.00**	57.03	72	1.26	89.38	240	2.69
13	6.74	0	-	11.62	5	0.43	26.08	32	1.23	44.44	37	0.83
14	2.19	0	-	3.66	0	-	8.61	2	0.23	14.46	2	0.14
15	2.14	0	-	0.00	0	-	4.85	0	-	6.99	0	-
16	0.00	0	-	0.00	0	-	0.00	0	-	0.00	0	-
17	2.22	0	-	1.71	3	1.75	13.27	3	0.23	17.20	6	0.35
18	0.33	0	-	0.00	0	-	9.51	2	0.21	9.84	2	0.20
19	0.00	0	-	0.00	0	-	0.37	0	-	0.37	0	-
20	5.16	0	-	0.00	0	-	7.06	0	-	12.22	0	-
21	0.41	0	-	0.00	0	-	4.93	0	-	5.34	0	-
22	0.52	0	-	0.00	0	-	7.42	0	-	7.94	0	-
23	0.00	0	-	0.00	0	-	2.91	0	-	2.91	0	-
24	2.39	0	-	0.00	0	-	3.93	0	-	6.32	0	-
25	3.61	0	-	0.00	0	-	4.76	0	-	8.37	0	-
26	0.91	0	-	0.00	0	-	5.83	0	-	6.74	0	-
27	0.63	0	-	0.00	0	-	0.00	0	-	0.63	0	-
28	3.47	0	-	0.00	0	-	2.27	0	-	5.74	0	-
29	3.42	0	-	0.00	0	-	0.03	0	-	3.45	0	-
Block Total	419.26	230	0.55	536.41	952	1.77	476.93	423	0.89	1432.60	1605	1.12
Total Canada	8.69	16	1.84	16.89	80	4.74	9.43	11	1.17	35.01	107	3.06
Total Unblocked	10.05	0	-	1.95	0	-	8.61	0	-	20.61	0	-
GRAND TOTAL	438.00	246	0.56	555.25	1032	1.86	494.97	434	0.88	1488.22	1712	1.15

Deriving a density estimate for a particular area is useful when assessing how a portion of a species range is utilized by the population. Bowhead densities were calculated for survey blocks only in 1985. Highest bowhead densities were calculated for block 5 in August (0.0011 whales/km^2) and September (0.0007 whales/km^2), and block 11 in October (0.0045 whales/km^2). Density estimates have been calculated for bathymetrically defined subregions (see Figure 24) in the Alaskan Beaufort Sea since 1979, as described in Appendix B. Overall (1979-85), highest monthly bowhead density was calculated for subregions D5 in August (0.130 whales/km^2), subregion A2 in September (0.912 whales/km^2) and subregion B3 in October (0.580 whales/km^2, Figure 23). The relatively high densities calculated for subregions A2 (0.912 whales/km^2), A3(0.604 whales/km^2), and A4 (0.477 whales/km^2) in September 1984 were the result of recurrent sightings of feeding bowheads near Pt. Barrow that year (Ljungblad et al., 1986a). Highest densities calculated for these subregions between 1979 and 1985 ranged from 0.0 to 0.099 whales/km^2. Prior to 1984, highest bowhead density in September had been calculated for subregion C3 (0.268 whales/km^2). Subregional density calculations for all years are presented and compared in Appendix B.

Migration Route, Timing,and Habitat Relationships

a. Median Depth Analysis of Migration Route

The fall bowhead migration route passes near or through areas off Alaska's North Slope that are designated for, or currently involved in, oil and gas development (see Figure 22A-D). Recently, concern has focused on the potential offshore displacement of the fall bowhead migration route by OCS oil and gas development activity. It was determined that one means of addressing this concern was to analyze bowhead sighting data for potential shifts in migratory route. A simple statistic was needed to define an axis of the bowhead fall migration route to address the question of potential shifts in the migration route. Median water depth for bowhead sightings made on random north-south line transect surveys was the statistic chosen because it (a) adequately defined the observed migratory axis as the depth contour such that half the sightings were at shallower (or equal) depths and half the sightings were at deeper (or equal) depths (b) is a robust statistic and

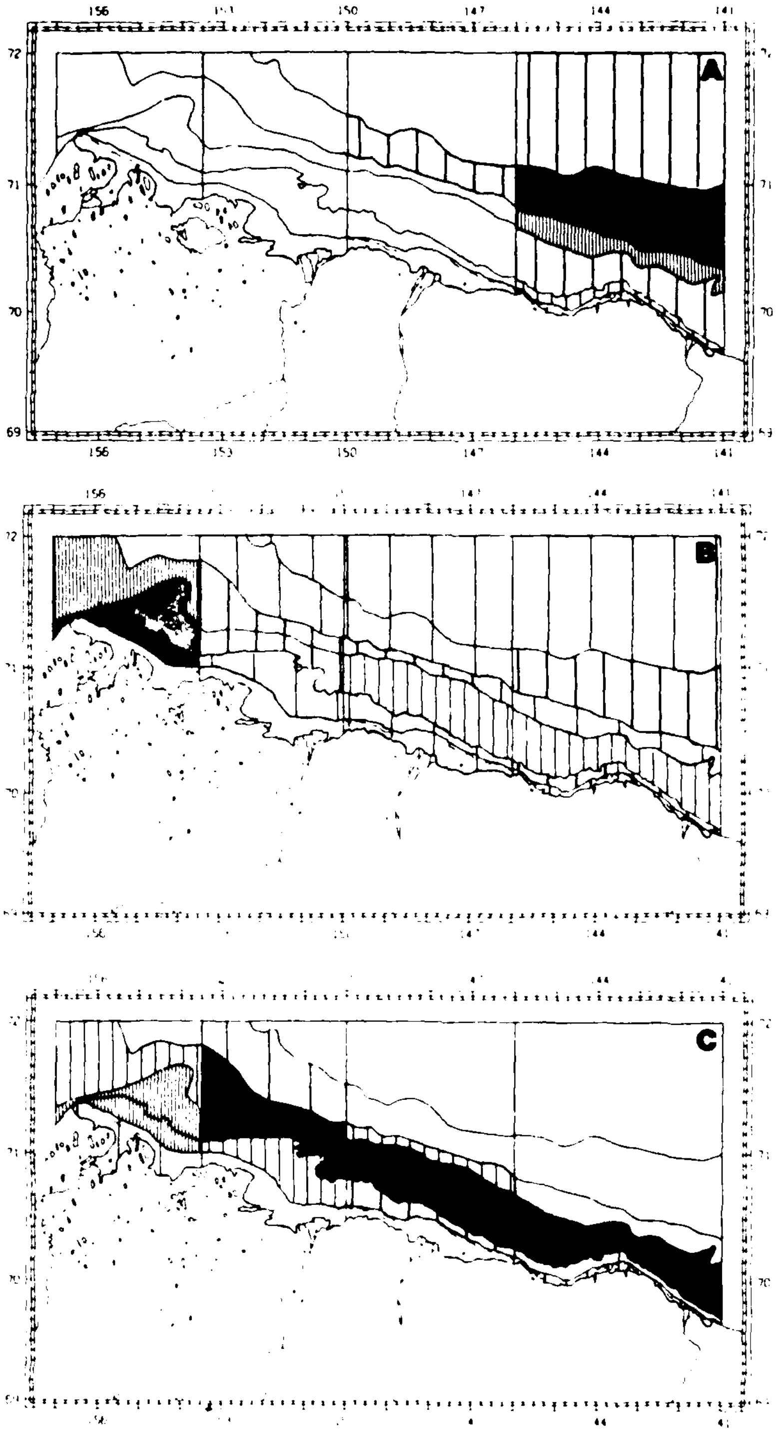

Figure 23. Highest annual bowhead densities/region calculated by month, fall 1979-85. Shading varies from white (representing 0 density) to black representing: 0.130 whales/km^2, August (A); 0.912 whales/km^2, September (B); 0.580 whales/km^2, October (C). Subregional densities presented here from Appendix B: Tables B-4(A), B-6(B) and B-8(C).

as such it is insensitive to unusually large or small depth values, to nonuniform aerial survey coverage, or to skewed distributions of data, and (c) was easy to compute from the existing data base. The analysis protocol specifying the use of median water depth to test for interannual shifts in the bowhead migration route is described in Chapters 4.2.3 and 5.3.3 of "Beaufort Sea Monitoring Program Workshop Synthesis and Sampling Design Recommendations" (Houghton et al., 1984).

The hypotheses tested via median depth analysis was prescribed in Houghton et al. (1984) as:

Ho_1: The axis of the fall migration of bowhead whales will not be altered during periods of increased OCS activities in the Alaskan Beaufort Sea.

Ho_2: Changes in bowhead migration patterns are not related to OCS oil and gas development activity.

Because of the bathymetry of the Alaskan Beaufort Sea, a seaward displacement of the fall migration route would be represented, via this analysis, as a shift to a deeper median depth.

Median depth at bowhead sightings was analyzed for the Alaskan Beaufort Sea study area between 141°W and 157°W, as well as for each of the four regions (A-D) utilized in density analysis (Figure 24). Region A extended from 153°30'W to 157°00'W, region B from 150°00'W to 153°30'W, region C from 146°00'W to 150°00'W, and region D extended from 141°00'W to 146°00'W. The depth at each bowhead sighting in the 1979-85 data base was derived using the computer program DEPTH that assigns a metric depth value to each 5 nmi of latitude by 20 nmi of longitude (approximately 9.25 km x 37 km) segment of the Beaufort Sea between 141°W and 157°W offshore to 72°N. This scaling assigns depth to sighting locations with an accuracy of approximately $\pm$ 3.5 m over most of the study area. At the shelf break between 100 m and 1000 m in regions B and C and between 10 m and 100 m at 156°30'W in region A, the accuracy was approximately $\pm$20 m. Values assigned to each segment were read off NOAA Provisional Chart 16004 when the DEPTH software was written. After depth values for all bowhead sightings were standardized across all years using DEPTH, it was determined that a 5-m shift in depth would correspond roughly to a 2 km displacement.

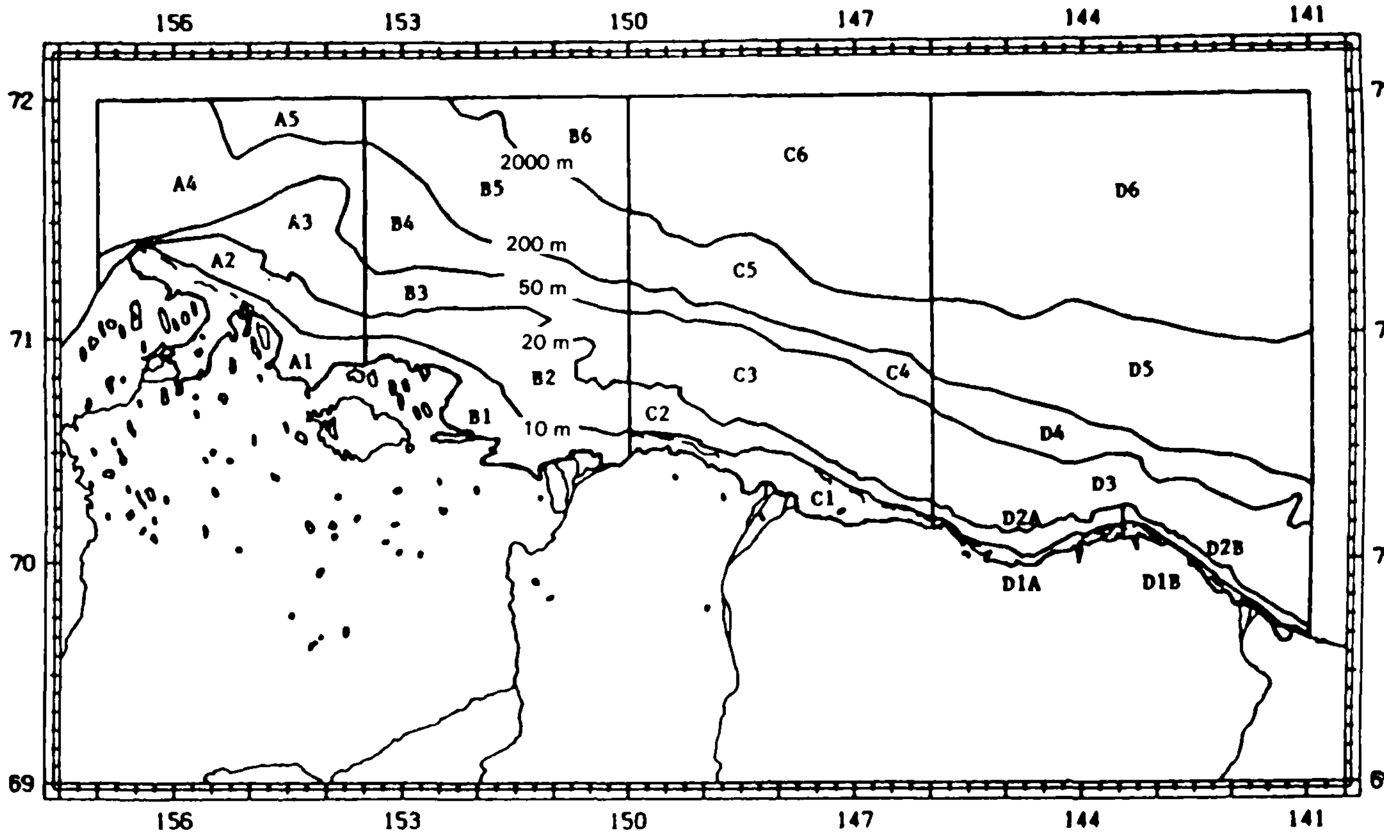

Figure 24. Four regions of the Alaskan Beaufort Sea study area stratified by contour intervals of 10 m, 20 m, 50 m, 200 m, and 2000 m.

The bowhead sighting data base was sorted such that only sightings made on random transect lines were stored onto a separate data file (MEDEPTH1). Sightings made during search surveys or enroute to survey blocks were omitted from the data file because such sightings do not represent a random sample of depths of all possible sightings. The median depth of sightings rather than of individual whales was used because each sighting represents an independent random observation, a necessary prerequisite to the derivation of confidence intervals for the sample median.

The depth values stored on the MEDEPTH1 data file were then ranked from lowest to highest values, and a sample median, a 99 percent confidence interval (C.I.) and the overall range of depth values were tabulated for each year.

The 99 percent C.I. was defined as:

$$L_1 = X_{C+1} \text{ ; lower limit}$$
$$L_2 = X_{n-C} \text{ ; upper limit}$$

When (2) = 0.01, C is determined from a table of critical values (Zar, 1984; Table B-26) where sample size $n \geq 8$. Confidence intervals were calculated at the 1 percent level to reduce the probability of incorrectly asserting that a change in migration route had occurred based on testing any one year to six others. For example, the probability of incorrectly determining a change occurred based on 1 of 5 tests is approximately 23 percent if tested at the 5 percent level, but only about 5 percent if tested at the 1 percent level (Houghton et al., 1984).

Because bowheads seen in the eastern Alaskan Beaufort Sea in August are generally farther offshore than whales seen in September and October and usually show no significant clustering about westerly swimming directions (i.e., are not migrating near-shore), the MEDEPTH1 data file was sorted such that only bowhead sightings made on random transects in September and October were stored (MEDEPTH2). The MEDEPTH2 depth values were ranked from lowest to highest and a sample median, 99 percent C.I. and overall sample range were tabulated. The MEDEPTH2 data file was then sorted by region (A-D), the values for each region were ranked and the above descriptive statistics were tabulated.

Tests for displacement in the axis of the migration assumed that annual median depths represented a "true" axis. The Mann-Whitney test, a standard test for a shift in median (Zar, 1984), was used to address the question of potential shifts in the axis of the bowhead whale fall migration route. The Mann-Whitney test is a nonparametric procedure performed on ranked samples where U and U' are calculated as:

$$U = n_1 n_2 + \frac{n_1(n_1 + 1)}{2} - R_1$$

$$U' = n_1 n_2 - U$$

where, n_1 = the smaller of the two samples being compared, if sample sizes are unequal

n_2 = the second sample set

R_1 = sum of the ranks of the n_1 sample

If either U or U' is as great or greater than the tabularized critical value at the chosen level of significance, the difference between the samples is significant. If the size of the smaller sample exceeds 20 or the size of the larger sample exceeds 40, the distribution of U approaches the normal distribution and a Z value is compared to the critical value t_{α} , where Z is calculated as:

$$Z = \frac{|U - \mu U| - 0.5}{\sigma U}$$

1 after μ_U and σ_U have been derived from the sample sizes as:

$$\mu U = \frac{n_1 n_2}{2} \quad ; \quad \sigma U = \sqrt{\frac{n_1 n_2 (N+1)}{12}}$$

A series of Mann-Whitney paired comparisons were made on annual median depths derived from the MEDEPTH2 data file with each year compared to all others such that annual and/or overall shifts in migration route over the 1979-85 study period could be evaluated. Subsequently, a series of paired comparisons were performed for each region (A-D) such that annual variations or potential shifts in median depth could be assessed for these smaller areas.

A total of 268 bowhead sightings have been made during random transect surveys since 1979 (Table 28). The timing and coverage of fall aerial surveys have changed from year to year with resultant shifts in areas surveyed, the amount of effort allotted to transect surveys, and therefore, the number of sightings made while on transect. For example, in 1979 and 1980 transect surveys were conducted primarily in or near the proposed state/federal oil lease areas (Figure 1: blocks 1 and 3), with search surveys flown in blocks 4 and 5. In 1981, attempts were made to conduct both behavioral studies (in blocks 4 and 5) and transect surveys (in blocks 1 and 3) from a single aircraft. The result was that prior to 1982, there was almost no survey effort north of the 200-m isobath, little effort west of 154°W, and relatively few sightings (n = 62, 23%) while on random transect lines. Since 1982, survey efforts have commenced in August (August survey efforts from 1979-81 were somewhat inconsistent) and have included survey blocks 1 through 12 (see Figure 1). As a result, more transect surveys were flown over the entire study area, and relatively more sightings were made while on random transects (n = 206, 77%) from 1982-85.

Table 28. Depth in meters at bowhead whale sightings made while flying random transects over the Alaskan Beaufort Sea, Fall 1979-85. Data was ranked from lowest to highest values. **Bold** depths indicate whales seen in August.

YEAR	1979	1980	1981	1982		1983	1984		1985
	11	11	15	7	**48**	5	5	29	7
	11	18	15	9	**48**	7	9	31	7
	11	18	18	13	49	18	9	33	9
	18	20	20	13	49	18	11	33	18
	18	20	22	13	49	18	11	35	18
	18	20	22	13	49	**40**	13	38	20
	18	20	29	18	49	42	15	40	20
	18	27	29	18	51	44	15	40	29
	18	27	33	18	**55**	48	15	40	29
	18	29	33	18	88	48	**18**	40	31
	20	40	35	20	145	49	18	40	38
	27	40	40	20	225	49	18	48	38
	27	(n=12)	46	20	**353**	**53**	18	48	46
	27		(n=13)	20	**366**	70	18	48	**55**
	27			22	**366**	82	18	49	57
	27			22	**366**	90	18	51	73
	29			22	**366**	90	18	51	145
	29			24	**366**	113	20	**53**	**146**
	29			27	**439**	145	20	55	225
	29			27	**549**	145	20	55	(n=19)
	29			27	**549**	154	20	55	
	29			29	**670**	154	20	**57**	
	29			31	**670**	293	20	60	
	31			31	**670**	366	22	60	
	35			35	**732**	556	22	62	
	35			38	**732**	732	22	64	
	35			38	**798**	732	26	86	
	38			38	**1006**	1290	26	102	
	38			38	**1222**	1290	26	110	
	40			38	**1829**	1290	27	123	
	40			38	**1829**	**1537**	29	466	
	42			38	**1848**	1902		(n=62)	
	42			38	**1848**	1829			
	46			38	**1857**	2005			
	48			40	**1873**	**2043**			
	49			40	**1884**	2122			
	75			40	**1884**	**2444**			
	(n=37)			42	**1902**	**2444**			
				44	**2036**	2561			
				44	**2232**	2698			
				48	**2799**	(n=40)			
					2799				
					2799				
					3293				
					(n=85)				

It should be noted that the depths listed in Table 28 may be different than those published in the NOSC annual reports (Ljungblad, 1981; Ljungblad et al., 1980, 1982-84). The depths published in annual reports prior to 1985 were read off nautical charts, often in the aircraft during the survey. To minimize error and to standardize depth - location assignment across all years, the DEPTH program was run on all data and in some cases caused depth values to change. Also, the sample size, sample median and 99 percent C.I. for the 1982 data cited in Houghton et al. (1984) is discrepant with that published here. Their larger sample size (n = 103) for 1982 September-October sightings is likely the result of using all data in Ljungblad et al. (1983) Appendix A, for which a sighting distance was listed. Sorting data by this method would result in the inclusion of sightings made on other than random transects, since the listing of a sighting distance in the appendix tables is **not** confined to whales seen on random transect.

The annual median water depth for bowhead sightings on random transect surveys conducted from August through October ranged from 20 m to 150 m (Table 29). Median depths for 1979-81 and 1984-85 data had a narrower 20 m to 31 m range, and 99 percent confidence intervals that overlapped in the 18 to 40 m range. These data correspond to years when few (0 to 4) bowhead sightings were made in August. In 1982 and 1983, 34 and six bowhead sightings, respectively, were made in August in relatively deep water (Table 28: **bold**), resulting in deeper median depths and broader confidence intervals for those years.

Overall, bowheads sighted on random transects in August (n = 48; Figure 25A) were further offshore and, therefore, in deeper water than whales seen during September and October (n = 220; Figure 25B). These whales were either part of an early offshore migratory component (Ljungblad et al., 1983), or were an extension of the summering population generally thought to be confined to the Canadian Beaufort Sea (Fraker et al., 1980). Because of their offshore distribution, and lack of significant clustering about westerly swimming directions (Ljungblad et al., 1986b), August bowhead sightings probably do not represent whales likely to be affected by current near-shore OCS development activities and were, therefore, eliminated from subsequent analysis.

The annual median water depth for bowhead sightings on transect surveys conducted in September and October ranged from 20 m to 145 m (Table 30). A plot of annual median depth contours across the Alaskan Beaufort Sea (Figure 26) demonstrates an overlap of the migration route with eastern (approx. 141°W to 147°W) OCS oil and gas lease areas, similar to that depicted in the distribution analysis (see Figure 22). Again, 1979-81 and 1984-85 data were most similar, with a median depth range of 20 to

Table 29. Median, confidence interval and overall range of water depth at bowhead whale sightings in the Alaskan Beaufort Sea, August-October 1979-85.

YEAR	(n)	MEDIAN	C.I.(99%)	RANGE
1979	(37)	29 m	20-35 m	11-75 m
1980	(12)	20 m	18-40 m	11-40 m
1981	(13)	29 m	15-40 m	15-46 m
1982	(85)	48 m	38-366 m	7-3293 m
1983	(40)	150 m	49-1290 m	5-2698 m
1984	(62)	29 m	20-40 m	5-466 m
1985	(19)	31 m	18-73 m	7-225 m

29 m and 99 percent confidence interval overlap within 18-40 m. Although the overall median depth for the 1982 sample was 38 m, the 99 percent confidence interval of 22-40 m overlapped that of 1979-81 and 1984 data. The median depth and confidence interval for 1983 data (145 m, 49-732 m) were deeper than that for any other year.

There appeared to be little variation in annual median depth across years 1979-85 as determined by the Mann-Whitney test (Table 31). The only year that was significantly different ($p < 0.001$) from all other years was 1983. The observed migratory route was farther offshore and in deeper water in 1983 than in all other years (Figures 26 and 27). The cause for this one-year difference in migratory route is unclear. Seismic exploration by geophysical vessels has been proposed as a disturbance source that might displace the bowhead migration (Albert, in Houghton et al., 1984). This seems an unlikely cause for the offshore distribution in 1983 however, because geophysical vessels were forced to operate primarily in Canadian waters or were confined to coastal Alaskan waters by the heavy ice conditions prevalent that year. Beaufort Sea ice coverage in 1983 was very heavy, similar to 1980 and to a lesser extent 1985 conditions, but much heavier than conditions in 1982 and 1984. The distribution of bowheads seen on random transects in 1982 and 1984 overlapped that of geophysical vessels, but heavy ice coverage in 1983 confined these vessels to near-shore waters, and there was little or no overlap with the observed bowhead distribution (Figure 28). Although geophysical vessels did not often use their air guns to conduct seismic surveys in 1983 due to the restrictive ice, the ships themselves were generating noise in the near-shore waters. Measurements

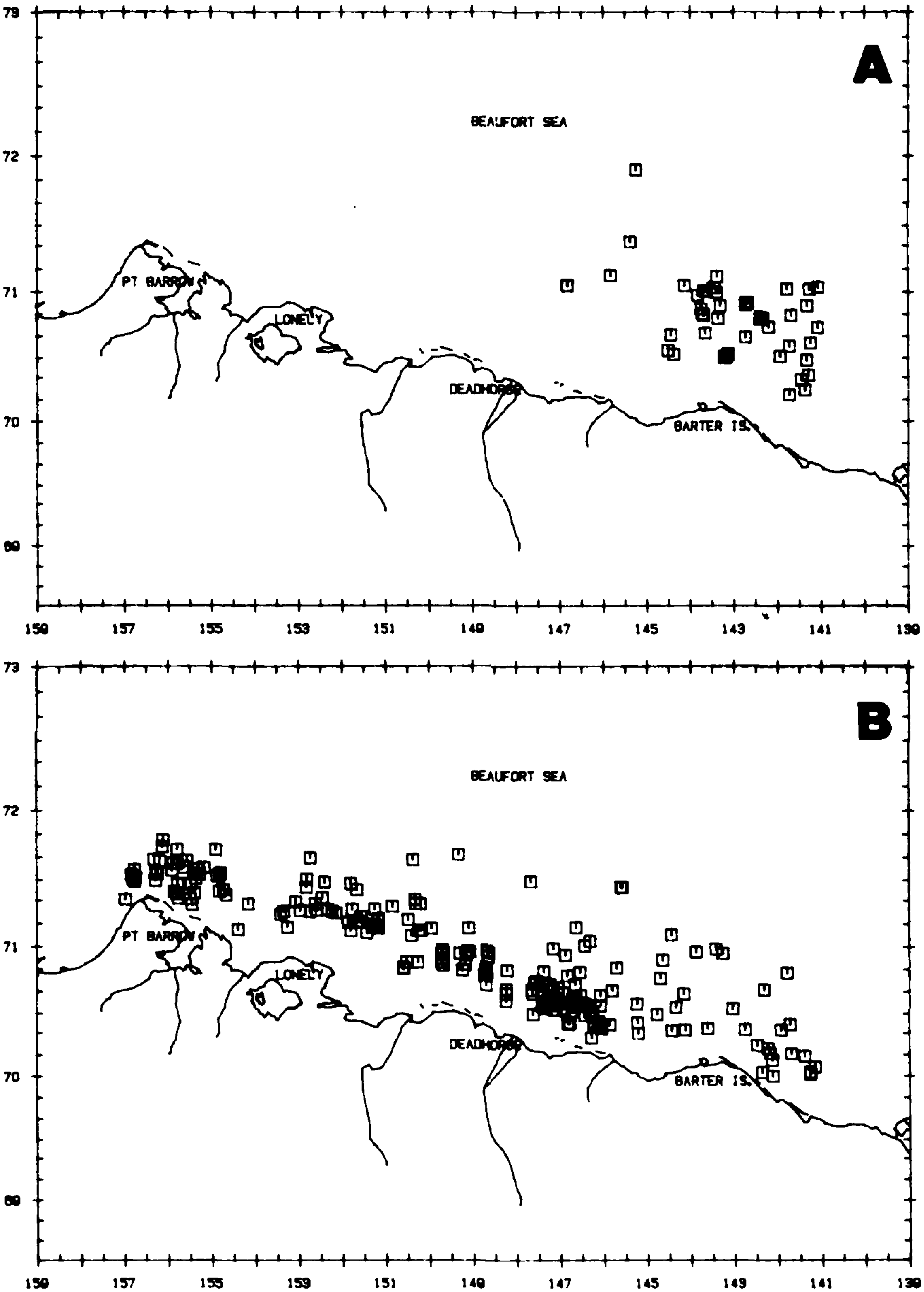

Figure 25. Distribution of bowhead whale sightings on random transect surveys in the Alaskan Beaufort Sea, 1979-85: 48 sightings, August (A); 220 sightings, September-October (B).

Table 30. Median, confidence interval and overall range of water depth at bowhead whale sightings in the Alaskan Beaufort Sea, September-October 1979-85.

YEAR	(n)	MEDIAN	C.I.(99%)	RANGE
1979	(33)	29 m	18-35 m	11-42 m
1980	(12)	20 m	18-40 m	11-40 m
1981	(13)	29 m	15-40 m	15-46 m
1982	(51)	38 m	22-40 m	7-2799 m
1983	(34)	145 m	49-732 m	5-2698 m
1984	(60)	28 m	20-40 m	5-466 m
1985	(17)	29 m	9-73 m	7-225 m

Table 31. Results of the Mann-Whitney test for comparisons of median water depth at bowhead sightings in the Alaskan Beaufort Sea, September-October 1979-85. **Bold** indicates comparisons that were statistically significant.

	1979 (n=33)	1980 (n=12)	1981 (n=13)	1982 (n=51)	1983 (n=34)	1984 (n=60)
1980	U=233 $p \leq 0.50$					
1981	U'=220.5 $p \leq 0.50$	U=95 $p \leq 0.50$				
1982	**U=1059.5** **Z=1.99** **$p < 0.05$**	U=414.5 Z=1.89 $p < 0.10$	U=409 Z=1.284 $p < 0.20$			
1983	**U=975.5** **Z=5.19** **$p < 0.001$**	**U=354** **$p < 0.001$**	**U=383.5** **$p < 0.001$**	**U'=1376** **Z=4.56** **$p < 0.001$**		
1984	U=1117.5 Z=1.02 $p \leq 0.50$	U=441 Z=1.22 $p \leq 0.50$	U=436 Z=0.66 $p \leq 0.50$	U'=1618 Z=0.52 $p \leq 0.50$	**U=1656.5** **Z=5.00** **$p < 0.001$**	
1985 (n=17)	U'=317.5 $p \leq 0.50$	U=123 $p \leq 0.50$	U=120.5 $p \leq 0.50$	U=471.5 Z=0.53 $p \leq 0.50$	**U=464** **$p \leq 0.001$**	U=516.5 Z=0.07 $p \leq 0.50$

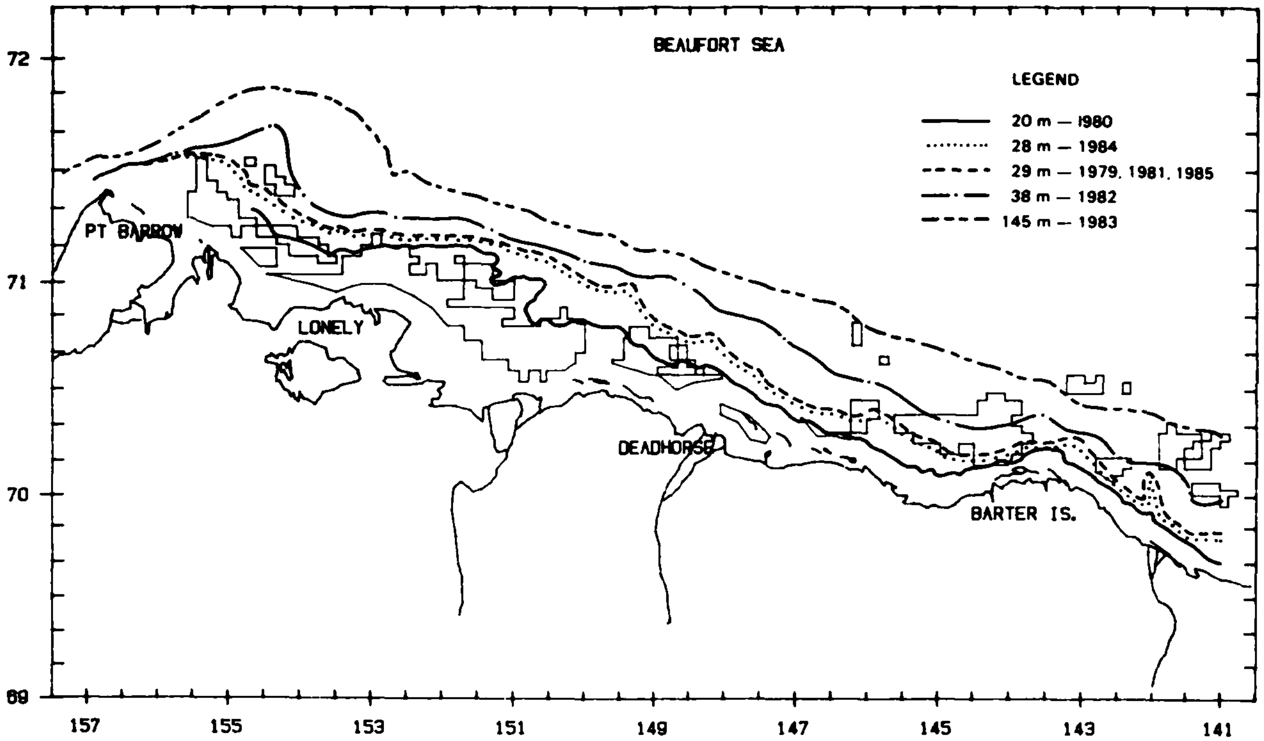

Figure 26. Annual median water depth contours depicting the bowhead migration route across the Alaskan Beaufort Sea September-October 1979-85. Outlined areas depict OCS oil and gas lease areas within the Beaufort Sea Planning Area of the Alaskan Beaufort Sea.

of geophysical vessel peak engine-noise levels in the 100-200 Hz frequency band include 104 dB re $1 uPa^2/Hz$ for a vessel at 1.4 km, 80 dB re $1 uPa^2/Hz$ for a vessel 38 km away and 78 dB re $1 uPa^2/Hz$ for a vessel 43 km away (Moore et al., 1984). Bowheads have been observed to avoid vessels of a variety of sizes when approached to within 1-4 km, and their avoidance of boats, although seemingly of short duration, has been described as more dramatic and consistent than to any other industrial activity studied (Richardson et al., 1985b). However, the magnitude of displacement (roughly 45 km) of the 1983 fall migration appears to be greater than that expected if caused by vessel disturbance. Even when bowheads were directly approached by geophysical vessels that were firing their air guns during experimental trials, behavior disturbance was not elicited until the vessels were within about 7.5 km of the whales, and was relatively short term ($\leq$60 min) (Ljungblad et al., 1986c). Displacement due to oil and gas activities other than vessels also seems unlikely, however, as ice conditions in 1983 forced many such activities to be curtailed.

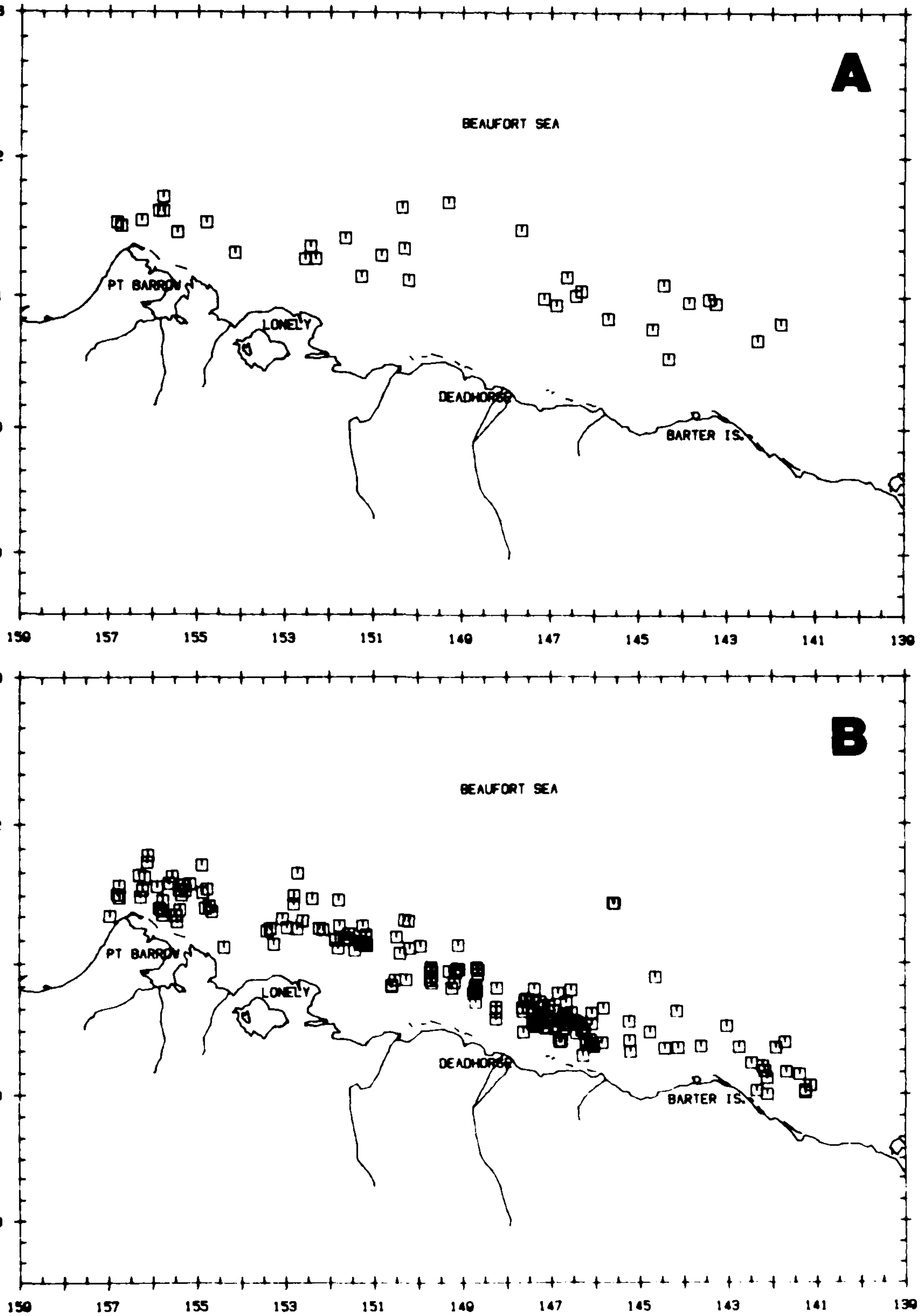

Figure 27. Distribution of 34 bowhead whale sightings, September-October 1983 (A), and 186 sightings September-October 1979-82 and 1984-85 (B).

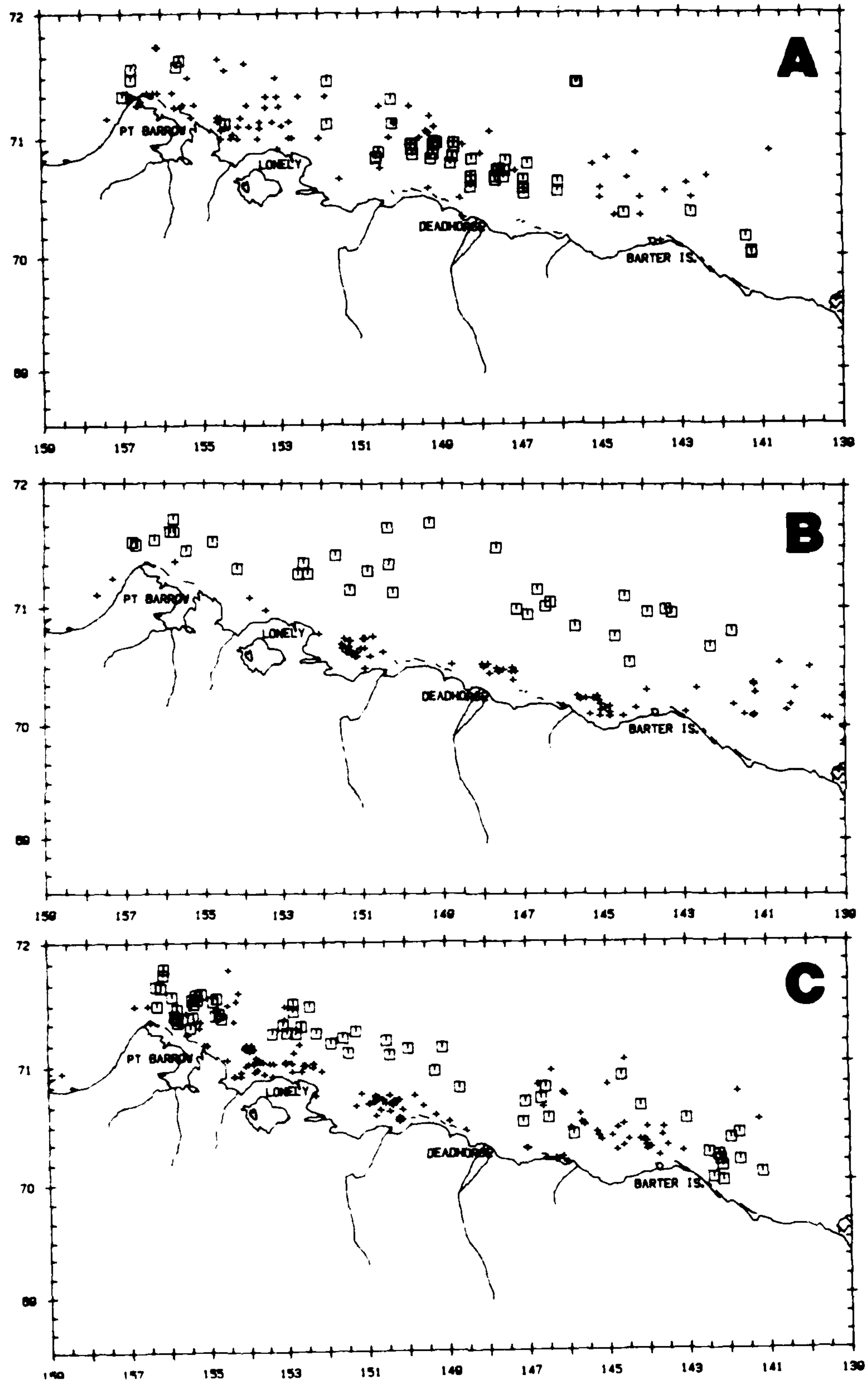

Figure 28. Distribution of bowhead whale sightings (□) and the daily "morning positions" for geophysical survey vessels (+): 1982(A); 1983(B); and 1984(C). Whale positions represent September-October sightings; vessel locations represent September only as most vessels were either dockside or out of the Alaskan Beaufort Sea by the end of September.

The only other case of significant difference of median depth between years was the 1979 and 1982 samples. The level of significance ($p < 0.05$) was not nearly as great as that for comparisons of any year with 1983 data (Table 31). This observed difference in median depth was probably related to differences in flight effort (i.e. surveys were flown offshore over deeper water in 1982, but not in 1979). When sightings with corresponding depths deeper than 200 m were deleted from the 1982 data ($n = 3$), the resultant median depth for 1982 (33 m) was **not** significantly different than 1979 ($U = 960.5$, $Z = 1.62$, $p < 0.20$).

The influence of ice coverage on the axis of the bowhead migration, as defined by median depth, appears to be indirectly related to ice effects on productivity. When median depth was related to average ice coverage observed during random transect survey and average ice coverage at random bowhead sightings for the 1981-85 survey seasons (Table 32), neither overall ice coverage nor ice coverage at bowhead sightings were significantly correlated with median depth ($r = 0.240$ and $r = 0.353$ respectively; $p < 0.50$). In other words, ice conditions did not appear to directly affect the annual median depth "axis" of the migration. The influence of heavy ice coverage on the productivity of bowhead prey communities over the continental shelf, however, may have contributed to the offshore distribution of bowheads observed in 1983. Between 1979-84, feeding bowheads were seen along the migration route in significantly shallower water and lighter ice coverage than non-feeding whales (Ljungblad et al., 1986a). Prey abundance depends upon light-dependent primary productivity. Ice deflects and diffuses incident light and in this way limits productivity (Schell et al., 1982). Therefore, 1983 prey abundance in the Alaskan Beaufort Sea may have been relatively low. The resultant lack of feeding opportunities may have had the secondary effect of displacing the migration offshore over deeper water. This suggestion of ice-related effects on bowhead distribution via the impact of ice coverage on productivity is speculative at best as there have been no comprehensive studies to determine this relationship. An alternate suggestion is that during the heavy ice year of 1983, bowheads encountered relatively lighter ice conditions along the 145-m isobath as a result of the effects of prevailing currents and wind on ice coverage. Each spring, an east-west lead system develops along a shear zone in the Beaufort Sea, and most whales are seen in or near this lead (Braham et al., 1980; Ljungblad et al., 1986b). Oceanographic conditions similar to those that influence spring ice habitat may have caused ice conditions along the

Table 32. Median depth, average annual ice coverage and average ice coverage at bowhead sightings, August-October 1981-85. All data from random transect lines only.

	Median Depth(m)	Overall Ice Conditions (%) $\bar{x}$	s.d.	n	Ice Conditions at Sightings (%) $\bar{x}$	s.d.	n	Statistical Comparison of Ice Conditions
1981	29	74	20	351	68	19	13	$t' = 1.08$, df = 13, $p < 0.50$
1982	48	46	36	909	41	37	85	$t' = 1.22$, df = 143, $p < 0.50$
1983	150	60	30	976	55	31	40	$t' = 1.26$, df = 1030, $p < 0.50$
1984	29	41	64	884	29	35	62	$t' = 2.62$, df = 123, $p < 0.01$
1985	31	44	39	433	19	33	19	$t' = 3.81$, df = 31, $p < 0.001$
1981-85		51	44	3553	40	37	219	$t = 4.85$, df = 3837, $p < 0.001$

145 m isobath to be more broken and/or relatively lighter than elsewhere and so influenced bowhead distribution by providing less restrictive migrating conditions. Although ice coverage at random bowhead sightings in 1983 was not significantly lighter (55%) than average ice coverage observed on random transects (60%, $t = 1.26$, $p < 0.50$; Table 32), subtle differences in ice coverage or make up (i.e., more broken ice) may have gone undetected because environmental data are updated only every 10 minutes (i.e., roughly every 40 km) in lieu of sighting data during random transect surveys. A ≤ 2 km wide lead-type channel of relatively lighter ice coverage, or changing ice composition, would not be definitively described via these methods.

Bowheads may generally prefer areas of relatively lighter ice coverage when migrating, although annual comparisons of overall ice conditions and ice conditions at random sightings did not uniformly support this contention (Table 32). In 1981-83, ice conditions at bowhead sightings were not significantly lighter ($p < 0.50$) than overall ice conditions on random transects. Bowheads were found in significantly lighter ice in 1984 ($t' = 2.62$, $p < 0.01$) and 1985 ($t' = 3.81$, $p < 0.001$), however, than overall conditions for those years. When data were pooled over five seasons (1981-85), average ice conditions recorded on random transects was significantly heavier (51%) than ice conditions at random bowhead sightings (40%; $t = 4.85$, $p < 0.001$), indicating that whales may seek out areas of relatively lighter ice during the fall migration.

To assess possible shifts in migration route over smaller areas, the median water depth, 99 percent confidence interval and overall depth range were calculated for each of the 4 regions of the Beaufort Sea study area (Table 33). There were no bowhead sightings while on transect in region A in 1979-81, nor in region D in 1980 due to aforementioned annual variations in flight effort. Annual median water depth in region A ranged from 18 m in 1984 to 113 m in 1983. The 99 percent confidence interval calculated for 1983 (5-154 m) encompassed that for 1984 (13-22 m). There were too few sightings in region A in 1982 and 1985 to calculate a confidence interval. The shallow median depth observed in region A in 1984 was likely related to sightings of feeding whales there. Bowheads seen feeding northeast of Point Barrow in 1984 were in significantly shallower water than whales feeding elsewhere in the Alaskan Beaufort Sea (Ljungblad et al., 1986a). The relatively deep median depth for the 1983 sample is consistent with the overall offshore distribution of whales discussed earlier, but was not significantly different from any other year (Table 34). In region B, annual median water depth ranged from 13 to 48 m (Table 33). Surprisingly, the median depth found in the 1983 sample was not significantly different than for 1981-85 samples, but was significantly deeper than that of 1979-80 (Table 34). In addition, median depth for 1984 sightings in region B was significantly deeper than those for 1979. As previously mentioned, flight effort extended further north and over deeper water in 1982-85 than in 1979-81. In 1984, depth at sightings in region B ranged from 11 m to 55 m, and in 1979 from 18 m to 29 m, such that the difference in annual median depth between these two years could have been effort dependent. Annual median depth in region C ranged from 24 to 1290 m (Table 33). Bowheads seen in region C in 1983 were in deeper water than whales seen there in any other year (i.e. 1983 sample range did not overlap any other year's range). As a result, the median depth for 1983 (1290 m) was significantly deeper than that for any other year (Table 34). There were no other cases of significant differences in region C. In region D, annual median depth ranged from 33 to 732 m (Table 33). The median depth for 1983 (732 m) was significantly deeper than 1979, 1981 and 1984 data (Table 34). There were no bowhead sightings in region D in 1980 and only one sighting in 1985.

When the 1983 data were omitted, the average median depth was deeper in region A ($\bar{x}$ = 36 m, 16.09 s.d., n = 3) and region D ($\bar{x}$ = 43.40 m, 9.76 s.d., n = 5) than in region B ($\bar{x}$ = 26.50, 13.26 s.d., n = 6) and region C ($\bar{x}$ = 29.17 m, 4.71 s.d.,

Table 33. Median water depth at bowhead whale sightings for four regions of the Alaskan Beaufort Sea, September-October 1979-85. -- = no sightings, * = insufficient sample size. All depths given in meters.

A
(153°30'-157°W)

	(n)	MEDIAN	C.I. (99%)	RANGE
1979			--	
1980			--	
1981			--	
1982	(6)	49	*	7-145
1983	(9)	113	5-154	5-154
1984	(22)	18	13-22	5-123
1985	(4)	41	*	7-145

B
(150°-153°30'W)

	(n)	MEDIAN	C.I. (99%)	RANGE
1979	(10)	18	18-29	18-29
1980	(4)	20	*	(20)
1981	(3)	22	*	18-22
1982	(8)	13	9-225	9-225
1983	(9)	48	18-2122	18-2122
1984	(15)	40	18-55	11-55
1985	(3)	46	*	7-225

C
(146°-150°W)

	(n)	MEDIAN	C.I. (99%)	RANGE
1979	(21)	29	27-35	11-40
1980	(8)	27	11-40	11-40
1981	(6)	24	*	15-40
1982	(30)	28	20-38	18-49
1983	(7)	1290	*	90-2698
1984	(9)	38	20-64	20-64
1985	(9)	29	18-38	18-38

D
(141°-146°W)

	(n)	MEDIAN	C.I. (99%)	RANGE
1979	(2)	42	*	(42)
1980			--	
1981	(4)	33	*	29-46
1982	(7)	49	*	40-2799
1983	(9)	732	49-2005	49-2005
1984	(14)	36	18-62	18-466
1985	(1)	57	*	(57)

Table 34. Results of the Mann-Whitney test for comparisons of annual median water depth at bowhead sightings in four regions (A-D) of the Alaskan Beaufort Sea, September-October 1979-85. * = insufficient sample size. **Bold** indicates comparisons that were statistically significant.

A

	1982 (n=6)	1983 (n=9)	1984 (n=22)
1983	U=30.5 $p \le 0.50$		
1984	U'=96 $p \le 0.10$	U'=130.5 $p < 0.20$	
1985 (n=4)	U=12 $p \le 0.50$	U=22.5 $p \le 0.50$	U=45 $p \le 0.50$

B

	1979 (n=10)	1980 (n=4)	1981 (n=3)	1982 (n=8)	1983 (n=9)	1984 (n=15)
1980	U'=28 $p \le 0.50$					
1981	U'=17.5 $p \le 0.50$	U'=8 $p \le 0.50$				
1982	U=50 $p \le 0.50$	U'=20 $p \le 0.50$	U'=15 $p \le 0.50$			
1983	**U'=83.5 $p < 0.001$**	**U=32 $p \le 0.005$**	U=24.5 $p < 0.10$	U=56.5 $p < 0.10$		
1984	**U=119.5 $p < 0.02$**	U=48 $p \le 0.10$	U=36 $p < 0.20$	U=81.5 $p < 0.20$	U'=91.5 $p < 0.20$	
1985 (n=3)	U'=20 $p \le 0.50$	U'=8 $p \le 0.50$	U=6 $p \le 0.50$	U'=13.5 $p \le 0.50$	U=17 $p \le 0.50$	U'=23 $p \le 0.50$

C

	1979 (n=21)	1980 (n=8)	1981 (n=6)	1982 (n=30)	1983 (n=7)	1984 (n=9)
1980	U=96.5 $p \le 0.50$					
1981	U=70 $p \le 0.50$	U=24.5 $p < 0.50$				
1982	U=318 Z=0.05 $p \le 0.50$	U=136.5 $p \le 0.50$	U=111.5 $p \le 0.50$			
1983	**U'=147 $p < 0.001$**	**U'=56 $p < 0.001$**	**U=42 $p \le 0.002$**	**U'=210 $p < 0.001$**		
1984	U'=127 $p < 0.20$	U=51 $p < 0.20$	U=41 $p < 0.20$	U'=186.5 $p < 0.10$	**U'=63 $p < 0.001$**	
1985 (n=9)	U=104.5 $p \le 0.50$	U=39 $p \le 0.50$	U=30 $p \le 0.50$	U=159 $p \le 0.50$	**U'=63 $p < 0.001$**	U=62 $p < 0.10$

D

	1979 (n=2)	1981 (n=4)	1982 (n=7)	1983 (n=9)	1984 (n=14)
1981	U'=6 $p \le 0.50$				
1982	U=9 $p \le 0.50$	**U=25 $p \le 0.05$**			
1983	**U=18 $p \le 0.05$**	**U=36 $p < 0.005$**	U=44 $p \le 0.50$		
1984	U'=18 $p \le 0.50$	U=30.5 $p \le 0.50$	U'=73 $p < 0.10$	**U'=119 $p < 0.001$**	
1985	*	*	*	U=8 $p \le 0.50$	U'=10 $p \le 0.50$

n = 6). Region D's average median depth was significantly deeper than region C's ($p < 0.005$) and region B's ($p < 0.02$), indicating that bowheads may migrate along a somewhat deeper isobath in the eastern (141°W to 146°W) Alaskan Beaufort Sea. There were no other instances of inter-regional differences in average median depth indicating that the bowhead migratory corridor may be roughly demarcated by the 20- to 40- meter isobath across the Alaskan Beaufort Sea west of 146°W.

b. Sightings Per Unit Effort (SPUE) Analysis of Migration Timing and Habitat Relationships

Each year considerable time has been spent describing interannual differences in the fall bowhead migration with regard to observed distribution, behavior, the timing of whale movements and associated ice conditions. In reviewing the progress that has been achieved since 1979 in describing the migration, one factor that has remained somewhat vague is the interpretation of the term "migration", specifically as it is applied to an aerial survey assessment of its progress. Migration is defined as a seasonal or periodic (mass) movement of animals away from and back to their breeding areas, and typically precedes and follows breeding seasons. Determining annual initiation and termination dates for the bowhead migration via aerial surveys is, by nature of methodological limitations, effort dependent. The criteria used to define the initiation of the migration has been the sighting of one or more adult bowheads swimming in a westerly or northwesterly direction (i.e., 210° -240° M) on two separate surveys within a five-day period. The termination of the migration has been generally defined as the date the last bowhead is seen in the Alaskan Beaufort Sea. These criteria, coupled with annual variation in survey effort, have resulted in migratory periods of varying duration (Table 35). For example, in 1979 the initiation of the migration period was based upon sightings of three whales and one whale swimming in a westerly direction on 20 August and 21 August respectively. Bowheads were next seen in the Alaskan Beaufort Sea on 7 September 1979 (n = ?, swimming west), but were not seen in great numbers until aggregations ($n \geq 20$) of whales were seen near Demarcation Bay on 24 and 26 September 1979. During this period, observed behaviors included feeding and slow westerly swimming. After 26 September, whales were seen west of Demarcation Bay with most whales swimming steadily.

Table 35. Summary of annual bowhead migration period, peak WPUE and date, number (percentage) of feeding bowheads, 5-day SPUE peak and SPUE peak period, average September/October ice coverage, and median depth at bowhead sightings in the Alaskan Beaufort Sea, fall 1979-85.

	1979	1980	1981	1982	1983	1984	1985
Migration Period Length (Days)	20 Aug-25 Oct (66)	4 Sep-9 Oct (35)	7 Sep-20 Oct (43)	2 Sep-17 Oct (45)	3 Sep-17 Oct (44)	7 Sep-20 Oct (44)	22 Sep 20 Oct (29)
WPUE: Peak	7.33	1.25	15.75	23.60	1.86	10.73	5.23
Date	14 Oct	18 Sep	28 Sep	16 Sep	24 Sep	26 Sep	6 Oct
Feeding Bowheads	50(25)	5(11)	41(14)	108(22)	14(8)	148(39)	35(25)
SPUE: Peak	2.69	0.61	6.70	2.53	1.35	1.60	0.97
Period	26-30 Sept	11-15 Sept	26-30 Sept	21-25 Sept	16-20 Sept	6-10 Oct	11-15 Oct
Average Sept/Oct Ice Coverage	$\leq$10%	$\geq$60%	$\leq$10%	0%	$\geq$60%	$\leq$10%	$\geq$40%
Median Depth	29 m	20 m	29 m	38 m	145 m	28 m	29 m

The last whale seen in the Alaskan Beaufort Sea was on 25 October, although surveys continued through 31 October 1979. In 1980 and 1981, very few surveys were conducted in the Alaskan Beaufort Sea prior to the migration initiation date in early September, so potential whale distribution and movements in August could not be fully described. Since 1982, surveys have been initiated in the Alaskan Beaufort Sea in August, and have extended offshore to 72°N. In 1982 and 1983, westerly swimming bowheads were seen in the Alaskan Beaufort Sea as early as 5 August and 2 August respectively. Because these whales were primarily offshore (see Figure 25) and in deep water, it was determined that they would not likely be affected by current near-shore OCS oil and gas activities and, therefore, these sightings were not incorporated in the defined migratory period. In 1984 and 1985, the few bowheads seen in August were relatively near shore in shallow water, as in 1979, but these whales were not swimming west. Therefore, the initiation of the 1984-85 bowhead migrations were in September. Determining the migration termination date was also affected by annual variations in the level and direction of survey effort. In 1980, 9 surveys were flown in the Alaskan Beaufort Sea after the migration termination date. Since 1981, zero to five surveys have been conducted after the last whale sighting. In 1985, the termination of the

migration was based upon efforts of three aircraft resulting in no bowhead sightings on two consecutive days. Resultant migratory periods have ranged from 35 to 66 days (Table 35). The 1985 bowhead migration extended from 22 September to 20 October, a shorter time period (29 days) than any previous year.

A description of fall migratory timing was initially based upon WPUE (Ljungblad et al., 1985), but this method was somewhat compromised because group size of feeding whales is significantly larger than that of non-feeding bowheads (Ljungblad et al., 1986a). Therefore, peak WPUE is strongly influenced by the number and timing of whales seen feeding during the migration. In 1985, 25 percent (n = 35) of all whales seen were feeding, and 66 percent (n = 23) of all feeders were seen on 9 September when WPUE was highest (see Figure 13). Similarly, in 1981, 1982 and 1984, peak WPUE was calculated for dates when groups of feeding bowheads were seen. Thus, peak WPUE/date indicates as much about when groups of feeding bowheads were seen during the fall migration as it does about the progress of the migration itself. Therefore, although WPUE/date has been used effectively in describing the progress of the spring bowhead migration (Braham et al., 1984; Ljungblad et al., 1986b), its utility in defining fall migratory progress is compromised somewhat by whales stopping to feed along the migratory route.

The timing of the observed fall bowhead migration described as the sightings per unit effort (SPUE = no. sightings/hour of survey effort) per five-day time period minimizes bias introduced when the number of whales are used (Figure 29). Sighting rates in August (1979-81) and the latter part of October reflect partial coverage during those time periods. Since 1979, the peak 5-day sighting period has occurred between 11-15 September and 11-15 October (Table 35, Figure 29). Peak 5-day SPUE periods were earlier in years of heavy ice coverage (1980: 11-15 September; 1983: 16-20 September) than in years when ice was light (Table 35). Peak sighting rate was highest (SPUE: 6.70) in 1981 when most September surveys were dedicated to observing bowhead behavior near active geophysical vessels (Fraker et al., 1985).

To analyze the interrelationship of migratory timing, behavioral parameters and habitat relationships as described by average annual September-October ice coverage and median depth, a multiple regression was performed on the data summarized in Table 35. The initiation of the migration was defined as the dependent variable (Y), and peak WPUE, percentage of feeding whales, SPUE peak,

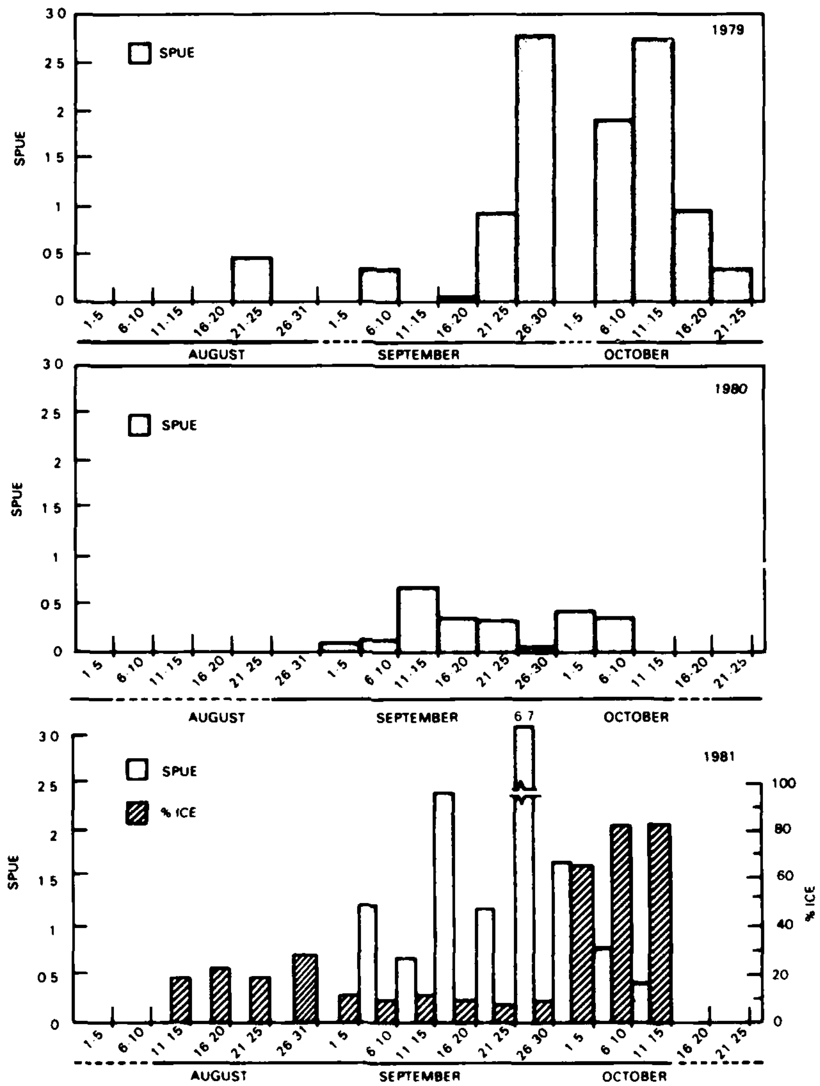

Figure 29. Bowhead whale sightings per unit effort (SPUE = no. sightings/hours of survey effort), and percentage of ice coverage, 1979-85. Ice coverage was not routinely recorded in 1979 and 1980, and therefore not incorporated in this analysis. A solid line (—) appears under periods of survey coverage; a dotted line (---) indicates periods without survey coverage.

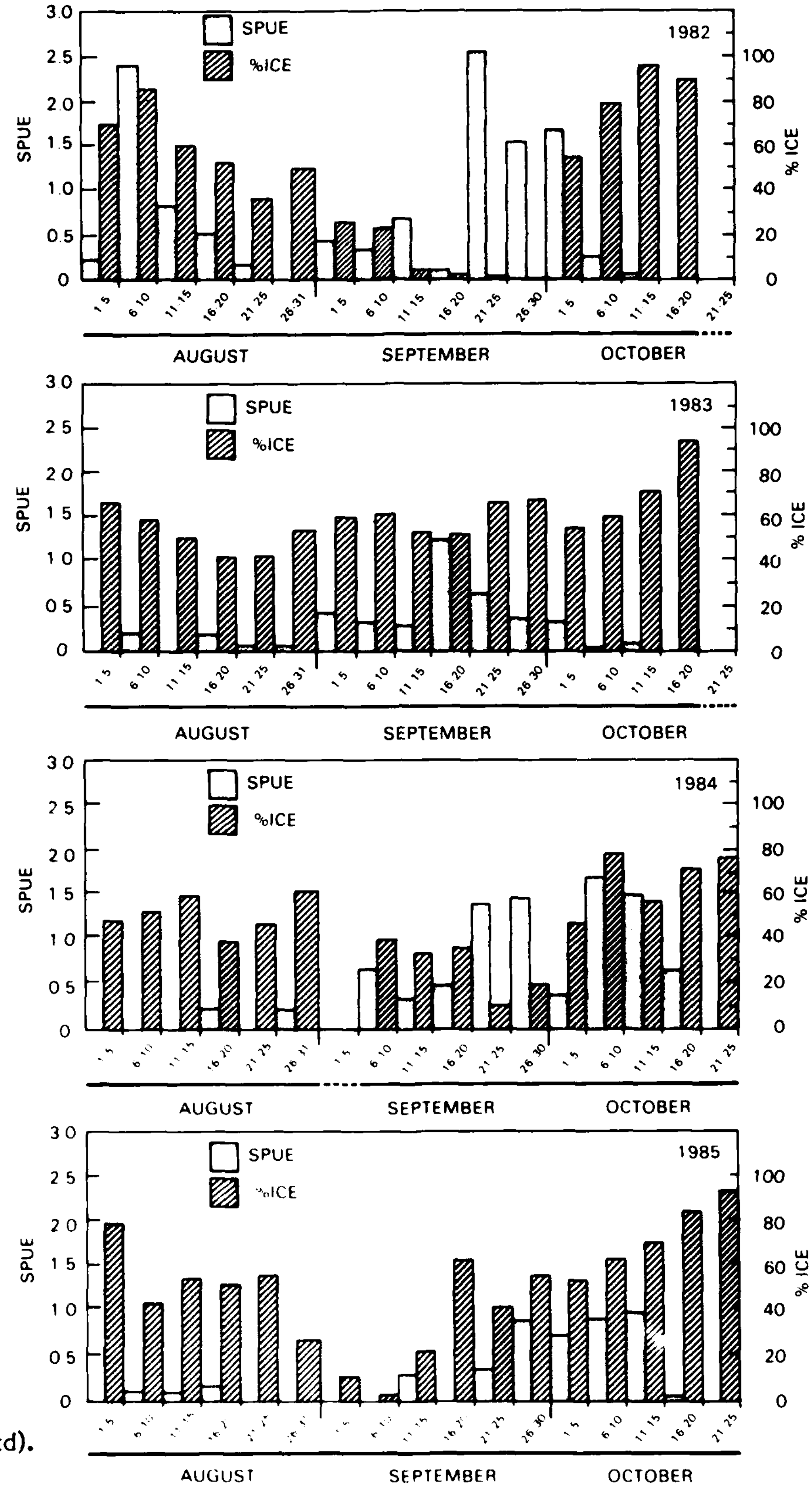

Figure 29 (contd).

Table 36. Matrix of correlation coefficients relating the migration initiation date (Y) to WPUE Peak (x_1), % feeding whales (x_2), SPUE peak (x_3), SPUE peak period (x_4), % ice coverage (x_5), and median depth (x_6).

		(x_1)	(x_2)	(x_3)	(x_4)	(x_5)	(x_6)	(Y)
Peak WPUE	(x_1)	1.0						
% Feeding	(x_2)	0.290	1.0					
Peak SPUE	(x_3)	0.561[1)]	-0.134	1.0				
SPUE Period	(x_4)	0.151	0.763[2)]	0.053	1.0			
% Ice	(x_5)	-0.849[3)]	-0.607[1)]	-0.568[1)]	-0.408	1.0		
Median Depth	(x_6)	-0.316	-0.490	-0.179	-0.356	0.484	1.0	
MIG. Initiation	(Y)	-0.089	0.095	-0.154	0.526	0.272	-0.090	1.0

1) $p < 0.20$
2) $p < 0.05$
3) $p < 0.02$

SPUE peak period, percentage of ice and median depth comprised the independent variables ($x_1 \ldots x_6$). The resultant correlation coefficients are summarized in Table 36. The strongest relationship was the negative correlation of ice coverage with peak WPUE ($r = -0.849$, $p < 0.02$). Ice coverage was also negatively associated with the percentage of feeding whales ($r = -0.607$, $p < 0.05$) and SPUE peak ($r = -0.568$, $p < 0.05$). As previously mentioned, WPUE is strongly influenced by the observed number of feeding whales, thus, it is not surprising that both WPUE and the percentage of feeding whales are negatively associated with heavy ice coverage, as ice coverage curtails productivity and in this way may limit bowhead feeding opportunities. The percentage of feeding whales was positively associated with peak SPUE period ($r = 0.763$, $p < 0.05$), indicating that in years of lighter ice when more whales are feeding, peak SPUE will be later than in heavy ice years when few whales are feeding. The annual median depth defining the axis of the bowhead migration was negatively associated with all parameters except ice coverage, although none of the relationships were significant (Table 36). The positive association of median depth with ice coverage may indicate that in heavy ice years, such as 1983, the migration proceeds farther offshore in deeper water than in light ice years. This may have indeed been the case in 1980, however, surveys were conducted only in relatively near-shore shallow water that year and whales migrating farther offshore in deeper water may have been missed.

The route, timing, and character of the fall bowhead migration across the Alaskan Beaufort Sea appears to be related to the extent of ice coverage and its effect on prey productivity and resultant bowhead feeding opportunities. Ice coverage limits primary and, therefore, secondary productivity (ie., bowhead food) by deflecting and diffusing incident light (Schell et al., 1982). The trend, described for five years of data, was for migrations in light-ice years to be longer, to result in a higher and later WPUE, and to be comprised of more feeding whales than migrations in heavy- ice years (Ljungblad et al., 1984b). As previously noted, the ice conditions encountered in 1985 were intermediate to years described as heavy (1980, 1983) or light (1979, 1981-82, 1984) (Ljungblad et al., 1984b). The timing and general character of the 1985 migration was most similar to that observed in 1979 when SPUE was relatively high from 26 September through 15 October. The influence of ice coverage on the fall migration may be indirectly related to the aforementioned effects of ice coverage on prey productivity. Understanding the specific effects of ice coverage on prey productivity in areas where bowheads have been seen feeding may better explain the impact of ice conditions on migratory dynamics.

In general, bowheads were seen each year most often in whatever ice coverage predominated during the latter half of September or first half of October when the majority of migrating whales were observed. Since 1981, 64 percent (n = 939) of all bowheads seen were in open water (i.e., ice coverage < 10%, Table 37). Eighty-five whales (6%) were in light (11-30%) ice coverage, 114 whales (8%) were in medium (31-60%) ice coverage and 331 whales (22%) were in relatively heavy ($\geq$60%) ice coverage. These data were not corrected for the potential effects ice coverage may have on the ability of observers to sight surfaced whales.

Probability of Detecting Bowhead Whales During the Fall Migration

The inability of observers to detect whales during aerial surveys will obviously affect distribution, relative abundance, density, and migratory route and timing results. Bowheads are missed by aerial observers either because (a) they are at the surface but go undetected, or (b) they are submerged as the aircraft passes over their location. The sightability of surfaced whales is affected by observer ability and by surface conditions (i.e., sea state and ice coverage). The relative ability of each observer to detect surfaced whales will vary with visual activity, attention span, the ability to withstand fatigue, experience with aerial surveys,

Table 37. Number and percent of bowheads found in each ice coverage class, fall 1981-85. Ice coverage was not routinely recorded in 1979-80.

Ice Coverage (%)	1981 No. (%)	1982 No. (%)	1983 No. (%)	1984 No. (%)	1985 No.(%)	Total No.(%)
0-10	234(81)	309(63)	46(27)	282(74)	68(49)	939(64)
11-20	9(3)	6(1)	0(0)	11(3)	1(1)	27(2)
21-30	5(2)	8(2)	22(13)	4(1)	19(14)	58(4)
31-40	1(0.5)	12(2)	13(8)	19(5)	3(2)	48(3)
41-50	10(3)	6(1)	4(2)	16(4)	0(0)	36(3)
51-60	1(0.5)	13(3)	12(7)	4(1)	0(0)	30(2)
61-70	6(2)	29(6)	27(16)	1(0)	1(1)	64(4)
71-80	19(7)	30(6)	23(13)	7(2)	29(21)	108(7)
81-90	3(1)	75(15)	25(14)	25(7)	5(3)	133(9)
91-100	0(0)	2(1)	0(0)	11(3)	13(9)	26(2)
TOTAL	288(100)	490(100)	172(100)	380(100)	139(100)	1469(100)

and seat position or type of window. These factors have not been documented for each observer during bowhead aerial surveys but have been described as having a significant ($p < 0.03$) effect on the outcome of other marine mammal surveys (Leatherwood et al., 1978). Magnusson et al. (1978) described an analysis, mathmatically similar to mark-recapture techniques, that provides an estimate of the proportion of whales at the surface that are missed by observers. This method requires three full-time observers, such that two observers can survey independently from the same side of the aircraft. Because aerial surveys for bowheads in the Alaskan Beaufort Sea have not been conducted in this manner, the best approximation of surfaced whales missed by observers may be that derived for aerial surveys of bowheads in the Canadian Beaufort Sea (Davis et al., 1982). The analysis performed by these researchers indicated that the raw bowhead count by a single observer on one side of the aircraft could be corrected for unseen surfaced whales by dividing that count by 0.685 $\pm$ s.e. 0.177 (Davis et al., 1982). Because this correction factor applies to sightings, it is potentially biased if large groups of whales are more easily detected than small groups or individuals, and it does not include any correction for submerged whales.

The effect of surface conditions on the sightability of surfaced whales was analyzed by comparing the perpendicular sighting distance of whales from the survey track line (see Figure B-1) to the percentage of ice coverage and sea state at the sighting. All sightings that had a perpendicular sighting distance (i.e. for which a clinometer angle was recorded) were entered into the analysis, regardless of whether the whales were seen during search or line transect surveys. Ice coverage and sea state were not routinely recorded at bowhead sightings in 1979 and 1980, thus, the analysis was performed on 1981-85 data only. Annual correlation coefficients (Table 38) indicated that in 1981, 1984, and 1985 ice coverage did not have a significant effect on sighting distance, but that sighting distance was significantly affected by ice coverage in 1982 ($r = -0.299$, $p < 0.001$) and in 1983 ($r = -0.260$, $p < 0.05$). Ice conditions in the Alaskan Beaufort Sea in 1982 were much lighter than those in 1983, so it is unlikely that similarities in survey conditions effected the results of the annual regressions. Sea state was negatively correlated with sighting distance in all years, but these associated coefficients were not statistically significant. When 1981-85 data were pooled, sighting distance was significantly negatively correlated with ice coverage ($r = -0.224$, $p < 0.001$) and negatively associated with sea state ($r = -0.041$, $p < 0.50$). Because the intercorrelation of ice coverage and sea state for the pooled sample was strong ($r = 0.431$, $p < 0.001$), it is not appropriate to describe a precise regression function using these regression coefficients (Zar, 1984: Section 20.4).

Because the pooled data indicates that ice coverage negatively affects the sightability of surfaced whales, the 0.685 correction factor derived by Davis et al. (1982) may be enhanced if paired comparisons of individual sighting rates could be completed with regard to different ice conditions. Ideally, the results of such a comparison would be the derivation of a series of correction factors weighted by the percentage of extant ice coverage. For example, Davis et al. (1982) noted that the probability of detecting surfaced whales in areas of "extensive pan ice" (i.e. $\geq$ 70% coverage) is high because an observer's attention can be focused for a "considerable period" on the relatively small, generally calm open water areas. Conversely, ice coverage of 30 to 70% may inhibit an observer's search pattern and not be sufficient to appreciably dampen high sea states, while calm water with light ice conditions (i.e. $\leq$30%) may facilitate an observer's search. In the absence of paired tests of sighting rates in a variety of ice conditions, 0.685 remains the best correction estimate for surfaced bowheads that are not detected by any individual observer.

Table 38. Correlation coefficients relating the effects of ice coverage and sea state surface conditions to the perpendicular sighting distance of bowhead whales from the survey track line.

	1981 (n=24)	1982 (n=172)	1983 (n=62)	1984 (n=89)	1985 (n=35)	1981-85 (n=386)
Ice coverage (%)	$r = 0.268$ $p < 0.50$	$r = -0.299$ $p < 0.001$	$r = -0.260$ $p < 0.05$	$r = -0.156$ $p < 0.20$	$r = 0.023$ $p < 0.50$	$r = -0.224$ $p < 0.001$
Sea state	$r = -0.380$ $p < 0.10$	$r = -0.009$ $p < 0.50$	$r = -0.041$ $p < 0.50$	$r = -0.082$ $p < 0.50$	$r = -0.266$ $p < 0.20$	$r = -0.041$ $p < 0.50$

Bowheads spend most of the time underwater. The probability that a whale will be at the surface when its location first comes into visual range may be described as:

$$\frac{s}{s + u} + \frac{t}{s + u} = \frac{s + t}{s + u}$$

Where (s) is the duration of surfacing, (u) is the duration of dives, and (t) is the duration of potential detectability (Eberhardt, 1978). Because only bowheads within 1 km of the survey track line have been considered when calculating bowhead density (see Appendix B), the parameter (t) was calculated as the time taken to travel 1 km at an average survey speed of 240 km/h; (i.e., t = 0.25 min.). Although the 0.25-minute figure seems a reasonable average estimate of duration of potential detectability, variation in survey speed, the potential detection of subsurface bowheads, or the detection of whales after the aircraft has passed their location will all affect the (t) estimate.

The dive and surface profiles of bowhead whales in the Alaskan Beaufort Sea were measured each fall 1981-84 during the course of surveys conducted to assess the effects of geophysical exploration on whale behavior (Fraker et al., 1985; Reeves et al., 1983; Ljungblad et al., 1984b; Ljungblad et al., 1985c). Most whales for which respiratory data were collected during these studies were either milling or feeding, not migrating. Based on the four sets of data, the proportion of time non-calf bowheads remained at the surface ranged from 11% to 18.5%, with an overall average of 13.6% (Table 39). The corresponding detection probabilities were calculated as 0.133 to 0.219, with a 0.160 overall average. Surface and dive times were reported for shallow (< 27-30 m) and relatively deep (30-50 m) water in

Table 39. Calculation of the probability that a bowhead whale will be at the surface and within an observer's field of view while conducting a random transect line.

	SURFACE TIME (S)			DIVE TIME (U)			Prop. of Time at surface	Detection Probability
	$\bar{x}$	s.d.	n	$\bar{x}$	s.d.	n		$\frac{S+.25}{S+U}$
A. September 1981								
Non-calves	1.82	0.94	42	13.31	6.81	20	12.0%	0.137
B. September 1982								
Non-calves	1.36	0.59	31	5.98	3.02	6	18.5%	0.219
Water depth								
< 27.45 m	1.33	0.67	42	6.83	4.07	19	16.3%	0.194
> 27.45 m	1.77	0.81	48	-	-	1	-	-
C. September 1983								
Non-calves	1.33	1.10	168	7.11	5.94	59	15.8%	0.187
Water depth								
< 30 m	1.04	0.63	88	9.08	6.66	27	10.3%	0.127
30-59 m	1.42	0.87	35	4.84	4.86	14	22.7%	0.267
D. September 1984								
Non-calves	1.19	0.87	155	9.61	8.14	30	11.0%	0.133
Water depth								
< 30 m	0.82	0.57	100	6.90	7.09	17	10.6%	0.139
30-59 m	1.88	0.90	55	13.16	8.32	13	12.5%	0.142
OVERALL AVERAGE								
Non-calves	1.42	0.24	4	9.00	2.81	4	13.6%	0.160
Water depth								
27-30 m	1.06	0.21	3	7.60	1.04	3	12.2%	0.151
30-59 m	1.69	0.20	3	9.00	4.16	2	15.8%	0.181

A. Fraker et al., 1985: Table 3
B. Reeves et al., 1983: Table 9
C. Ljungblad et al., 1984b: Table 11
D. Ljungblad et al., 1985b: Table 1

1982-84. The proportion of time that bowheads in shallow water remained at the surface ranged from 10.3% to 16.3% with a 12.2% three-year average. Corresponding detection probabilities for whales in shallow water ranged from 0.127 to 0.194, with a 0.151 average. The proportion of time that whales in deeper water remained at the surface ranged from 12.5% to 22.7%, with 15.8% average for the two years for which data was available. Detection probabilities for whales in 30-59 m deep water ranged from 0.142 to 0.267, with a two-year 0.181 average. Although the proportion of surface time for whales in 30-50 m deep water was longer than for whales in shallower water, these differences were not significant ($X^2 = 0.050$, $p < 0.90$).

The results presented in Table 39 indicate that bowheads in the Alaskan Beaufort Sea were at the surface 13.6% of the time, and that 16% of the whales within 1 km of a random transect survey leg would be expected to be detectable. Since 1979, an annual average of 137 bowheads have been seen within one kilometer of the aircraft while conducting random transect surveys. When corrected for surfaced whales that are missed by aerial observers (i.e., 137 0.685), this number represents 200 whales. If these 200 whales comprise the component of whales at the surface as the aircraft passes over (i.e., 16%), then on average 1250 whales are actually represented by the annual average of 137 bowheads seen on transect.

Behavior and Sound Production

The proportion of bowhead behaviors observed in 1985 were roughly similar to previous years (Table 40). Migratory behaviors (swimming and diving) comprised 44 percent of all behaviors seen, a lower proportion than 1979-81 and 1983, the same as 1982 and a higher proportion than 1984. The percentage of socializing whales was highest in 1982 (56%), 1984 (63 %), and 1985 (56%). In contrast, Würsig et al. (1985) reported a relatively high socializing rate for bowheads summering in Canadian waters in 1981, relatively low rates of socializing in 1982 and 1984, and an intermediate rate in 1983.

Eleven percent of all whales seen in 1985 were resting, a greater proportion than all years except 1981 (18%; Table 41). Feeding whales comprised 25 percent of the sample, equal to that of the seven-year average. Milling whales comprised 6 percent of the sample. Cow-calf association represented 9 percent of all observations, equal to that in 1982 but greater than all other years. Five percent of all behaviors were displays, a proportion similar to all years except 1983 (14%).

Table 40. Proportions of migratory and social bowhead behaviors observed, fall 1979-85.

	1979	1980	1981	1982	1983	1984	1985
Migratory	59	85	64	44	62	37	44
Social	41	15	36	56	38	63	56

When bowhead calls recorded aboard secondary aircraft (Ljungblad et al., 1984b; 1985c) were added to fall 1983-84 call samples, the 1985 sample contained fewer calls than any other year analyzed (Table 42). Call rate ranged from 0.9 in 1982, to 11.3 in 1983. The relatively high call rate in 1983 was nearly an order of magnitude greater than the three-year combined average of 1982, 1984-85 ($\bar{x}$ = 1.3, s.d. = 0.4). Würsig et al. (1985) suggest that the high call rate (45.3) reported for bowheads summering in the Canadian Beaufort Sea in 1982 was the result of recordings made in relatively deep water that year, and state that there was a significant positive correlation between call rate and water depth when five years of data were analysed. No such correlation was found in the 1982-85 Alaskan Beaufort Sea bowhead call data base ($r = -0.026$, $p < 0.50$, $n = 30$), although the average water depth at sonobuoy locations was in fact deeper in 1983 (427 m) than in 1984 (36 m) and 1985 (21 m), but shallower than in 1982 (721 m). The underwater propagation of bowhead calls is also affected by sea state and percent of ice cover. There was a weak trend for call rate to increase with increasing ice coverage ($r = 0.286$, $p < 0.20$, $n = 30$), and an insignificant negative association of call rate with increasing sea state ($r = -.078$, $p < 0.50$, $n = 30$). As previously mentioned, 1983 was a year of heavy ice coverage. The trend for bowhead call rates to be somewhat higher in heavy ice coverage is consistent with the high call rate recorded that year. In addition, 32% of all calls recorded in 1983 were "up" calls, a higher percentage than any other year (Table 42). These calls are very similar to "up" calls recorded near southern right whales (*Eubalaena glacialis*) that Clark (1983) suggests function as long distance "contact" signals that bring whales together. Perhaps bowheads migrating through heavy ice conditions call more often and use "contact" calls to coordinate their movements.

Table 41. Bimonthly summary of bowhead behavior, fall 1979-85.

Behavior	Year	1-15 Aug	16-31 Aug	1-15 Sep	16-30 Sep	1-23 Oct	Total (%)
Swim	1979	--	4	2	6	57	69 (50)
	1980	--	--	7	5	2	14 (31)
	1981	--	2	38	70	19	129 (51)
	1982	64	7	5	77	29	182 (37.5)
	1983	27	8	6	37	16	94 (55)
	1984	2	8	13	46	60	129 (34)
	1985	5	3	3	17	30	58 (42)
	Total	**98**	**32**	**74**	**258**	**213**	**675 (42)**
Dive	1979	--	3	0	3	7	13 (9)
	1980	--	--	0	17	8	25 (54)
	1981	--	0	5	20	8	33 (13)
	1982	5	3	4	16	3	31 (6.5)
	1983	2	0	4	5	1	12 (7)
	1984	0	0	4	2	6	12 (3)
	1985	0	0	0	2	1	3 (2)
	Total	**7**	**6**	**17**	**65**	**34**	**129 (8)**
Rest	1979	--	0	0	0	2	2 (1)
	1980	--	--	0	0	0	0 (0)
	1981	--	0	17	22	6	45 (18)
	1982	18	7	2	5	8	40 (8)
	1983	8	0	3	1	0	12 (7)
	1984	1	1	0	7	15	24 (6)
	1985	2	0	2	5	6	15 (11)
	Total	**29**	**8**	**24**	**40**	**37**	**138 (9)**
Feed	1979	--	0	0	43	7	50 (36)
	1980	--	--	5	0	0	5 (11)
	1981	--	0	8	22	11	41 (16)
	1982	0	0	23	85	0	108 (22)
	1983	4	0	0	0	10	14 (8)
	1984	0	8	0	138	2	148 (39)
	1985	0	0	23	0	12	35 (25)
	Total	**4**	**8**	**59**	**288**	**42**	**401 (25)**
Mill	1982	12	12	7	50	0	81 (17)
	1984	0	0	0	46	0	46 (12)
	1985	0	0	6	2	1	9 (6)
	Total	**12**	**12**	**13**	**98**	**1**	**136 (8)**
Cow-Calf	1979	--	0	0	0	4	4 (3)
	1980	--	--	0	0	2	2 (4)
	1981	--	0	0	2	2	4 (2)
	1982	8	6	6	0	2	22 (4.5)
	1983	0	2	4	4	6	16 (9)
	1984	0	0	0	4	6	10 (3)
	1985	0	0	0	6	6	12 (9)
	Total	**8**	**8**	**10**	**16**	**28**	**70 (4)**
Display	1979	--	0	0	0	1	1 (1)
	1980	--	--	0	0	0	0 (0)
	1981	--	0	0	0	0	0 (0)
	1982	0	2	7	12	1	22 (4.5)
	1983	8	0	7	7	2	24 (14)
	1984	0	1	0	0	10	11 (3)
	1985	2	0	0	1	4	7 (5)
	Total	**10**	**3**	**14**	**20**	**18**	**65 (4)**
*Total	1979	--	7	2	52	78	139*
	1980	--	--	12	22	12	46
	1981	--	2	68	136	46	252*
	1982	107	37	54	245	43	486*
	1983	49	10	24	54	35	172
	1984	3	18	17	243	99	380
	1985	9	3	34	33	60	139
	Total	**168**	**77**	**211**	**785**	**373**	**1614 (100)**

*Behavior was not recorded for 98 whales: 58 in 1979; 36 in 1981; and 4 in 1982. (--) = no sightings.

Table 42. Percent of bowhead calls of each category, fall 1982-85.

	CALL TYPE								
		Simple				Complex			
Year	Call Rate	Up %	Down %	Const. %	Inflect %	High %	Growl %	Trumpet %	No. Calls
1982	0.9	20	27	8	17	8	10	10	2012
1983	11.3	32	15	7	18	2	22	4	1194
1984	1.1	21	17	1	23	3	19	16	182
1985	1.9	19	25	3	11	3	35	4	170

All bowhead call types recorded during the falls of 1982-85 were qualitatively very similar to those recorded and quantitatively described for the spring migration (Ljungblad et al., 1982; Clark and Johnson, 1984), and the relative proportions of simple and complex calls were roughly similar each year (Table 42). Simple FM calls comprised 61 to 80 percent of the bowhead fall call sample with a four-year average of 70 percent; conversely, 20 to 39 percent of bowhead calls recorded in fall were complex AM signals with a 30 percent four-year average. This four-year fall proportion of simple/complex calls (70/30) contrasts with two-year spring (52/48; Moore et al., 1984) and five-year summer (87.5/12.5; Würsig et al., 1985) proportions, indicating there may be some seasonal differences to the call types produced. The interpretation of these differences is compromised in several ways. Although the procedures for call categorization have been agreed upon by the different analysts, call samples have largely been reviewed and counted aurally resulting in an inherent reliance on the listener's hearing and subjective judgement. The time and cost of analyzing all recorded sounds via spectral processes have, to date, been prohibitive. Therefore, there is probably some subjective bias to the proportion of calls reported. Secondly, and perhaps more important, are the circumstances (i.e., environmental conditions and/or researcher's motivation) involved in recording data. In spring and fall, sonobuoys were usually dropped near groups of whales, and occasionally when whales were not seen to acoustically monitor an area for whale presence. In summer, sonobuoys were always dropped near whales (Würsig et al., 1985).

Although statistically significant correlations between observed behaviors and call production have not been demonstrated for bowheads, general trends of socializing whales producing higher proportions of complex calls and swimming or resting whales producing mostly tonal FM calls have been reported (Ljungblad et al., 1984a, 1985b; Würsig et al., 1985). Such differences likely result in different proportions of sounds being recorded depending on the behavior of the subject whales that a researcher chooses to drop a sonobuoy near. In addition, variation in sea state and ice conditions will affect the attenuation of each call type somewhat differently, depending on their physical qualities, and therefore, the proportion of calls recorded in the sample.

Because acoustic monitoring is becoming more common in bowhead research (Clark et al., 1985; Clark et al., 1986; Cummings and Holliday, 1983), it is increasingly important that the data recorded be analyzed for differences in call rate, or call type proportions, by season and/or by the number of whales near (≤ 10 km) the sonobuoy, such that inferences may be drawn from the data. To test for possible correlations, 87 bowhead call samples were tabularized with concomitant behavior, call rate, and the proportion of call types (Table 43). The sample included recordings made in spring (April/May, n = 12), summer (August, n = 51) and fall (September/October, n = 24). Forty-five samples were recorded, usually in August, near whales summering in the Canadian Beaufort Sea (Würsig et al., 1982, 1983, 1984a). Seven August recordings were made either in the eastern Alaskan Beaufort Sea, or within 50 km of the U.S.-Canadian border (Ljungblad et al., 1983, 1984), and were considered "summer" data for this analysis. A behavior index was calculated for the samples as described for the fall 1985 acoustic data (p. 49). For 1980-83 data tabulated from Würsig et al. (1982-84), an average number of whales and average call rate was calculated for samples where ranges were given in the original data. Also, for 1982-83 data transcribed from Würsig et al. (1983-84) the "loud sounds," presumed to be produced by whales ≤ 5 km from the sonobuoy, were used because associated behaviors were listed for these sounds. Call samples were omitted if there were no behavioral observations associated with them.

In spring, call rate ranged from 2.9 to 22.6 ($\bar{x}$ = 9.91, s.d. = 7.23), in summer from 0.0 to 5.49 ($\bar{x}$ = 5.59, s.d. = 9.42), and in fall from 0.0 to 93.1 ($\bar{x}$ = 23.13, s.d. = 26.36). Although the spring and summer call rates were not significantly different ($t' = 1.75$, $p < 0.10$), average fall call rate was significantly higher than spring ($t' = 2.29$, $p < 0.05$) and summer ($t' = 3.17$, $p < 0.005$).

Table 43. Summary of 87 bowhead call samples recorded since 1980, including number of whales, behavior index, call rate, percentage of call types, and number of calls.

Sample No.	Date	No. Whales	Behavior	Behavior Index	Call rate (calls/wh-h)	up (%)	down (%)	const (%)	inflect (%)	high (%)	growl (%)	trumpet (%)	No. Calls
1	26 April 1982	28	RE/MS/SW	0.6	4.6	23	11	0	0	9	46	11	35
2	28 April 1982	8	RE/MS/SW	1.4	10.5	23	19	6	0	0	49	3	31
3	3 May 1982	35	RE/SW	0.9	3.2	42	19	9	7	4	19	0	96
4	4 May 1982	33	SW/MS/AS/DY	2.5	4.8	8	10	4	3	8	47	20	250
5	5 May 1982	11	MS/SW	1.5	19.2	12	15	3	4	2	41	23	127
6	13 May 1982	45	RE/MS/SW/AS	1.2	2.9	22	10	10	3	0	49	6	125
7	14 May 1982	12	SW	1.0	13.6	25	18	11	8	0	34	4	95
8	30 April 1983	11	MS/AS/SW	2.1	3.6	10	10	0	20	0	40	20	10
9	1 May 1983	10	AS/SW	3.8	6.4	14	29	0	14	0	38	5	21
10	2 May 1983	15	SW/AS	3.7	22.6	51	5	0	3	1	39	1	282
11	4 May 1983	4	SW/AS	3.0	20.2	26	21	0	3	0	50	0	34
12	10 May 1983	9	SW	1.0	7.3	5	24	3	13	0	55	0	38
13	7 Aug 1980	7	MS	2.0	9.1	26	6	3	0	0	65	0	31
14	22 Aug 1980	14	FE	3.0	1.0	37	45	9	9	0	0	0	11
15	23 Aug 1980	5	FE	3.0	2.6	60	10	0	0	0	30	0	10
16	29 Aug 1980	9	MS	2.0	1.3	14	21	0	58	0	7	0	14
17	5 Aug 1981	5	SW	1.0	30.5	30	8	12	10	12	2	26	84
18	5 Aug 1981	5	SW	1.0	13.0	39	0	0	0	15	0	46	13
19	10 Aug 1981	2	RE	0.0	0.0	0	0	0	0	0	0	0	0
20	10 Aug 1981	5	MS	2.0	1.1	0	0	0	0	25	0	75	4
21	18 Aug 1981	10	SW	1.0	1.4	58	12	2	2	7	7	12	42
22	18 Aug 1981	25	FE	3.0	0.4	37	27	0	0	0	9	27	11
23	18 Aug 1981	25	FE	3.0	0.0	0	0	0	0	0	0	0	0
24	18 Aug 1981	25	FE	3.0	1.1	58	5	2	2	9	21	3	57
25	19 Aug 1981	6	FE	3.0	0.0	0	0	0	0	0	0	0	0
26	19 Aug 1981	6	MS	2.0	1.1	75	0	0	25	0	0	0	4
27	19 Aug 1981	6	MS	2.0	0.5	100	0	0	0	0	0	0	1
28	19 Aug 1981	4	MS	2.0	0.3	100	0	0	0	0	0	0	1
29	23 Aug 1981	6	MS	2.0	2.4	50	30	10	0	10	0	0	10
30	23 Aug 1981	12	AS	5.0	10.1	19	5	2	2	13	31	28	363
31	23 Aug 1981	12	AS	5.0	0.0	0	0	0	0	0	0	0	0
32	24 Aug 1981	12	SW	1.0	0.9	30	40	0	0	10	0	20	10
33	25 Aug 1981	15	SW	1.0	0.5	100	0	0	0	0	0	0	7
34	25 Aug 1981	4	MS	2.0	4.2	100	0	0	0	0	0	0	4
35	25 Aug 1981	4	PL/MS	2.8	1.5	100	0	0	0	0	0	0	1
36	25 Aug 1981	5	SW	1.0	3.7	55	23	0	0	3	16	3	31
37	8 Sep 1981	6	AS	5.0	22.4	8	3	1	0	22	8	58	121
38	8 Aug 1982	6	RE/SW/MS	1.0	17.5	71	5	20	1	0	0	3	98
39	14 Aug 1982	1	SW	1.0	22.9	57	0	6	12	0	0	25	16
40	14 Aug 1982	3	SW	1.0	6.2	19	12	25	6	0	0	38	16
41	16 Aug 1982	6	SW	1.0	8.3	7	28	5	7	2	12	39	43
42	19 Aug 1982	9	SW/PL/CC	2.1	3.8	18	14	50	6	0	6	6	49
43	19 Aug 1982	11	SW/MS/CC	1.8	4.0	16	28	18	11	1	17	9	100
44	23 Aug 1982	11	SW/MS/CC	1.9	18.2	17	38	16	16	3	3	7	474
45	24 Aug 1982	8	SW/MS/DY	1.9	4.1	47	0	12	6	6	0	29	17
46	24 Aug 1982	8	SW	1.0	6.5	36	14	21	20	3	0	6	102
47	24 Aug 1982	4	RE	0.0	1.7	100	0	0	0	0	0	0	6

Table 43 (contd).

Sample No.	Date	No. Whales	Behavior	Behavior Index	Call rate (calls/wh-h)	up (%)	down (%)	const (%)	inflect (%)	high (%)	growl (%)	trumpet (%)	No. Calls
48	31 Aug 1982	1	SW	1.0	8.8	29	0	0	7	7	0	57	14
49	31 Aug 1982	2	RE/SW	0.5	0.0	0	0	0	0	0	0	0	0
50	9 Aug 1983	12	MS	2.0	0.0	0	0	0	0	0	0	0	0
51	15 Aug 1983	6	SW	1.0	0.2	100	0	0	0	0	0	0	1
52	15 Aug 1983	6	SW	1.0	1.7	13	10	10	25	0	42	0	31
53	17 Aug 1983	15	MS	2.0	2.3	37	18	18	9	9	9	0	11
54	18 Aug 1983	13	MS/SW	1.5	0.4	40	0	0	20	0	40	0	5
55	22 Aug 1983	6	DY/FE	3.5	2.6	27	27	0	18	10	18	0	11
56	22 Aug 1983	10	RE/SW	0.5	1.0	86	0	0	0	0	7	7	14
57	26 Aug 1983	6	FE	3.0	0.0	0	0	0	0	0	0	0	0
58	7 Aug 1982	10	SW/MS/CC	1.7	2.1	50	30	20	0	0	0	0	10
59	8 Aug 1982	19	SW/MS	1.3	6.1	12	19	13	5	16	22	13	78
60	15 Aug 1982	16	RE/MS/CC	1.9	9.0	34	7	15	4	21	2	17	82
61	16 Aug 1982	14	RE/SW/MS/CC	2.1	5.0	12	3	6	0	12	58	9	41
62	18 Aug 1982	9	MS/DY	2.9	8.2	56	3	35	0	3	3	0	37
63	14 Sep 1982	18	MS	2.0	11.4	17	11	6	10	12	12	32	143
64	15 Sep 1982	32	SW/FE/CC	2.5	8.7	25	22	12	21	4	10	6	277
65	16 Sep 1982	60	SW/MS/FE	1.8	11.3	17	36	6	20	5	10	6	1014
66	24 Sep 1982	133	SW/MS/FE/CC/DY	2.1	3.0	21	19	9	17	12	4	18	330
67	2 Aug 1983	3	SW/DY	4.3	54.9	0	0	0	0	21	50	29	28
68	9 Aug 1983	8	SW/FE/DY	2.6	2.8	0	0	0	0	25	75	0	4
69	12 Sep 1983	14	DY/MS/SW	2.5	28.7	41	17	15	13	2	9	3	523
70	21 Sep 1983	3	SW/CC	3.0	29.6	12	21	0	0	0	67	0	24
71	26 Sep 1983	2	SW	1.0	65.0	62	15	0	8	0	15	0	13
72	2 Oct 1983	5	CC/SW	3.4	93.1	27	15	1	23	1	30	3	684
73	14 Oct 1983	3	SW/DY	2.7	91.7	27	27	0	23	0	23	0	22
74	11 Sep 1984	4	SW	1.0	2.2	0	0	0	100	0	0	0	2
75	18 Sep 1984	4	SW	1.0	37.5	0	0	0	78	0	22	0	18
76	21 Sep 1984	3	SW/MS	1.7	14.4	62	31	0	7	0	0	0	13
77	24 Sep 1984	50	SW/FE	2.8	2.2	21	37	11	5	0	26	0	19
78	26 Sep 1984	7	MS	2.0	0.0	0	0	0	0	0	0	0	0
79	3 Oct 1984	9	RE/SW	0.6	33.3	37	20	0	17	0	26	0	30
80	9 Oct 1984	18	RE/SW/DY	3.1	14.6	16	13	0	18	5	18	30	100
81	11 Oct 1984	2	RE	0.0	0.0	0	0	0	0	0	0	0	0
82	17 Oct 1984	1	SW	1.0	0.0	0	0	0	0	0	0	0	0
83	11 Sep 1985	18	RE/MS/FE	1.7	0.7	11	0	0	33	0	56	0	9
84	23 Sep 1985	8	MS/SW	1.5	16.3	47	27	0	0	3	23	0	30
85	25 Sep 1985	4	RE/SW	0.5	21.1	24	29	8	21	5	13	0	38
86	27 Sep 1985	11	SW/MS/CC	2.1	14.6	15	17	2	8	4	54	0	53
87	13 Oct 1985	6	RE/SW	0.8	33.3	2	35	2	8	0	35	18	40

Sample No. 13-37: Würsig et al. 1982, Table 5, p. 113

Sample No. 38-47: Würsig et al. 1983, Table 9, "loud sounds", p. 85

Sample No. 48-57: Würsig et al. 1984, Table 6, "loud sounds", p. 82

Table 44. Matrix of correlation coefficients relating number of bowhead whales (Y) to behavior index (x_1), call rate (x_2), percentage of call types (x_3-x_9) and total number of calls (x_{10}). Coefficients represent the results of a multiple regression analysis of the data summarized in Table 43.

		(x_1)	(x_2)	(x_3)	(x_4)	(x_5)	(x_6)	(x_7)	(x_8)	(x_9)	(x_{10})	(Y)
Behavior index	(x_1)	1.0										
Call rate	(x_2)	0.143	1.0									
FM calls: up	(x_3)	-0.155	-0.070	1.0								
down	(x_4)	0.011	0.167	-0.122	1.0							
constant	(x_5)	-0.068	-0.076	-0.004	0.212[2)]	1.0						
inflect	(x_6)	-0.114	0.176	-0.226[2)]	0.053	-0.043	1.0					
high	(x_7)	0.235[2)].	0.019	-0.211[2)]	-0.090	0.009	-0.160	1.0				
AM calls: growl	(x_8)	0.173	0.216[2)]	-0.316[4)]	0.107	-0.173	0.000	0.091	1.0			
trumpet	(x_9)	0.088	0.042	-0.212	-0.099	0.002	-0.130	0.579[5)]	-0.123	1.0		
No. Calls	(x_{10})	0.195[1)]	0.305[4)]	-0.099	0.267[3)]	0.144	0.110	0.095	0.047	0.040	1.0	
No. Whales	(Y)	0.088	-0.163	-0.102	0.222	0.118	0.020	0.143	0.056	0.010	0.422[5)]	1.0

1) $p < 0.10$ 4) $p < 0.05$
2) $p < 0.05$ 5) $p < 0.001$
3) $p < 0.02$

A multiple linear regression was performed on the data summarized in Table 43, resulting in several significant correlations (Table 44). The only significant correlation with behavior index was "high" (FM_7) calls ($r = 0.235$, $p < 0.05$, $n = 87$), and there was a trend for the number of calls to be greater with higher behavioral indices ($r = 0.195$, $p < 0.10$, $n = 87$). Call rate was positively correlated with the number of calls ($r = -0.305$, $p < 0.005$, $n = 87$), and with "growl" (AM_1) calls ($r = 0.216$, $p < 0.05$, $n = 87$). As in the fall 1985 sample, call rate was positively associated with "down" (FM_2) calls, and negatively associated with the number of whales, but these correlations were not significant. Significant intra-call type correlations were found with "up" (FM_1), "down" (FM_2) and "trumpet" (AM_2) calls. All correlations with "up" calls were negative; the four that were significant were with "inflect" (FM_6) calls ($r = 0.226$, $p < 0.05$, $n = 87$), with "high" (FM_7) calls ($r = -0.211$, $p < 0.05$, $n = 87$), with "growl" (AM_1) calls ($r = -0.316$, $p < 0.005$, $n = 87$) and with "trumpet" (AM_2) calls ($r = -0.212$, $p < 0.05$, $n = 87$). Down calls were significantly correlated with "constant" (FM_5) calls ($r = 0.212$, $p < 0.05$, $n = 87$), with the number of calls ($r = 0.267$, $p < 0.02$, $n = 87$), and the number of whales ($r = 0.222$, $p < 0.05$, $n = 87$). Trumpets were significantly

correlated with "high" (FM_7) calls ($r = 0.579$, $p < 0.001$, $n = 87$). The number of calls was significantly correlated with the number of whales ($r = 0.422$, $p < 0.001$, $n = 87$). These correlations suggest that bowhead calls are in some way interrelated, and not simply a series of discrete events. As Clark (1982) reported for southern right whales, the bowhead call repertoire may be best described as a continuum where certain call types are more common than others, and with some inter-call associations within the repertoire framework.

The occurrence of significant correlation between call types suggests that call production changes with concomitant behavior. The ability to infer something about the number and/or behavior of whales associated with a particular call sample is occluded, however, by the apparent flexibility of bowhead calling behavior and the inability of aerial observers to positively identify and watch calling whales. There was no clear association of call rate with the number of whales nor of their behavior. A review of Table 43 indicates instances where swimming bowheads (i.e., behavior index = 1.0) produced call rates ranging from 0.2 calls/wh-h to 60 calls/wh-h, while milling whale (behavior index = 2.0) call rate ranged from 0.0 to 11.4 calls/wh-h, and so on. If bowhead and right whale calling strategies are similar, however, certain assumptions about call type proportions may be practical. Clark (1982; 1983) reported that resting right whales produced "up" calls, swimming whales produced "up" and "down" calls, mildly active and fully active whales produced mostly "high" calls with some "growls", "ups" and "downs", and that sexually active whales produced mostly "growls" and "high" calls with some "up", "down" and "constant" calls. A researcher at a listening station may infer general activity states, and whether whales are likely grouped, from these associations. For example, a series of "up" calls may indicate lone stationary or swimming whales (note: bowhead "up" calls were negatively associated with all other call types), while a series of "growls" and "trumpets" with interspersed FM calls may indicate a social group of whale near the hydrophone.

Recruitment

Bowhead calves have been seen from August through October, resulting in annual recruitment estimates ranging from 0.01 to 0.08, and an overall estimate of 0.03 (Table 45). The 1985 recruitment estimate (0.05) was the same as that calculated in 1982, and higher than that calculated for all other fall seasons, except 1983 (0.08). The recruitment estimate for 1983 (7.56%) was significantly

Table 45. Sightings and estimated Gross Annual Recruitment Rate (GARR)* of bowhead calves by two-week interval, fall 1979-85.

Year	1-15 Aug	16-31 Aug	1-15 Sep	16-30 Sep	1-24 Oct	Total
1979	0	0	0	0	6(0.05)	6(0.03)
1980	0	0	0	0	1(0.08)	1(0.02)
1981	-	0	1(0.02)	1(0.01)	1(0.02)	3(0.01)
1982	5(0.05)	6(0.16)	4(0.07)	7(0.03)	1(0.02)	23(0.05)
1983	2(0.04)	1(0.10)	3(0.12)	3(0.06)	4(0.11)	13(0.08)
1984	0	0	0	2(0.01)	3(0.03)	5(0.01)
1985	0	1(0.09)	0	3(0.09)	3(0.05)	7(0.05)
TOTAL	7(0.04)	8(0.09)	8(0.04)	16(0.02)	19(0.04)	58(0.03)

*GARR = Number calves/total number bowheads

higher than those in 1979 (3.05%; $X^2 = 6.85$, $p < 0.01$), 1981 (1.04%; $X^2 = 13.54$, $p < 0.001$), and 1984 (1.32%; $X^2 = 14.46$, $p < 0.001$), and was also significantly higher than all years (except 1983) combined ($X^2 = 10.12$, $p < 0.001$).

The variation in bimonthly and yearly recruitment estimates may be due to age class segregation within the population. Segregation of bowhead age classes in the eastern Beaufort Sea has been demonstrated via photogrammetric length frequency studies (Cubbage et al., 1984; Davis et al., 1983). Different age classes were found in different locations each year. Chapman (1984) noted that to derive an accurate GARR, given the existence of segregation, all components of the population must be sampled and then combined, weighed by the number of whales comprising each component. The GARR provided here was not corrected for such segregation because the component(s) of the population sampled is not known with certainty for any year. Thus, the derived GARR (Table 45) represents only the observed portion of the bowhead population in the Alaskan Beaufort Sea during the stated time period.

Table 46. Monthly summary of gray whale sightings (number of sightings/number of whales), fall 1980-85.

	August	September	October	November	TOTAL
1980	0[a]	0	44/125	60/163	104/288
1981	33/55	0	0	0	33/55
1982	0	5/18	6/8	0	11/26
1983	2/14	1/2	6/10	0	9/26
1984	16/33	7/70	6/12	0	29/115
1985	0	0	0	0	0
TOTAL	51/102	13/90	62/155	60/163	186/510

a) 3/3, Canadian Beaufort Sea; Rugh and Fraker, 1981.

GRAY WHALE

Distribution and Relative Abundance

Since 1980, 186 fall sightings of 510 gray whales have been made (Table 46), with 64 percent (n = 328) of all whales in the Bering Sea, and 36 percent (n = 182) in the Chukchi Sea. In October and November 1980 and August 1981, surveys were flown and gray whales seen in the northern Bering Sea. Since 1982, all fall surveys have been conducted in the Beaufort and northwestern Chukchi Sea.

Gray whale fall distribution ranged from the southeast coast of St. Lawrence Island and the Chirikov Basin in the northern Bering Sea through the northeast Chukchi Sea to Pt. Barrow (Figure 30). In August, grays were seen along the southeast coast of St. Lawrence Island, in the Chirikov Basin between 167°W and 170°W, just north of the Bering Strait, and in the northeastern Chukchi Sea along the coast between Icy Cape and Pt. Barrow (Figure 30A). Three gray whales were seen in the Canadian Beaufort Sea by researchers on the primary aircraft (N780) in August 1980 (Rugh and Fraker, 1981), but were not plotted in Figure 30A as the sightings were well east of 139°W. In September (1982-84), grays were seen in the northeastern Chukchi Sea between Wainwright and Barrow (Figure 30B). In

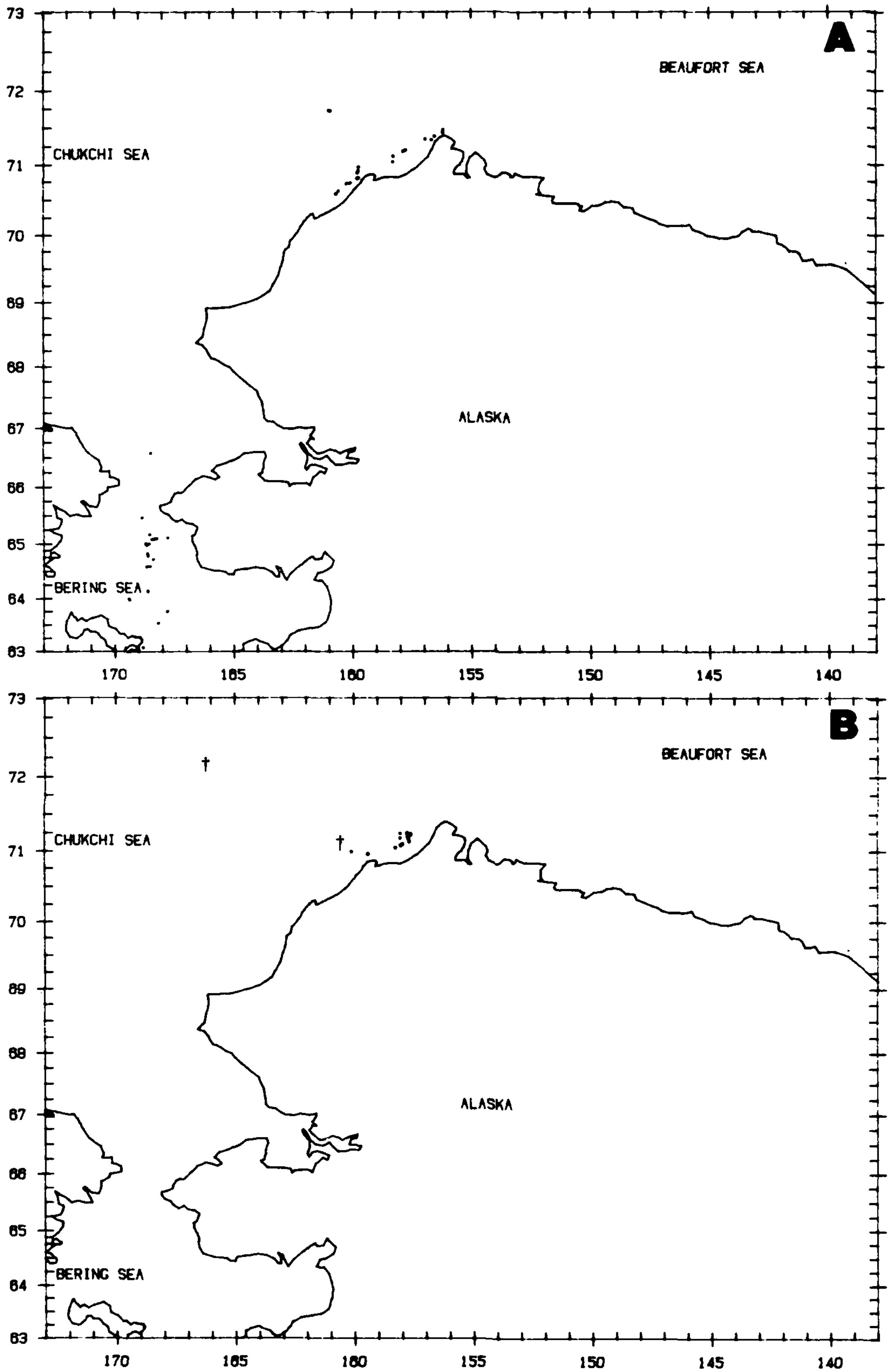

Figure 30. Distribution of 186 sightings of 510 gray whales, fall 1980-85; 51 sightings of 102 whales in August (A); 13 sightings of 90 whales in September (B); (†September 1985 sightings by USFWS researchers; K. Frost, personal communication[2]).

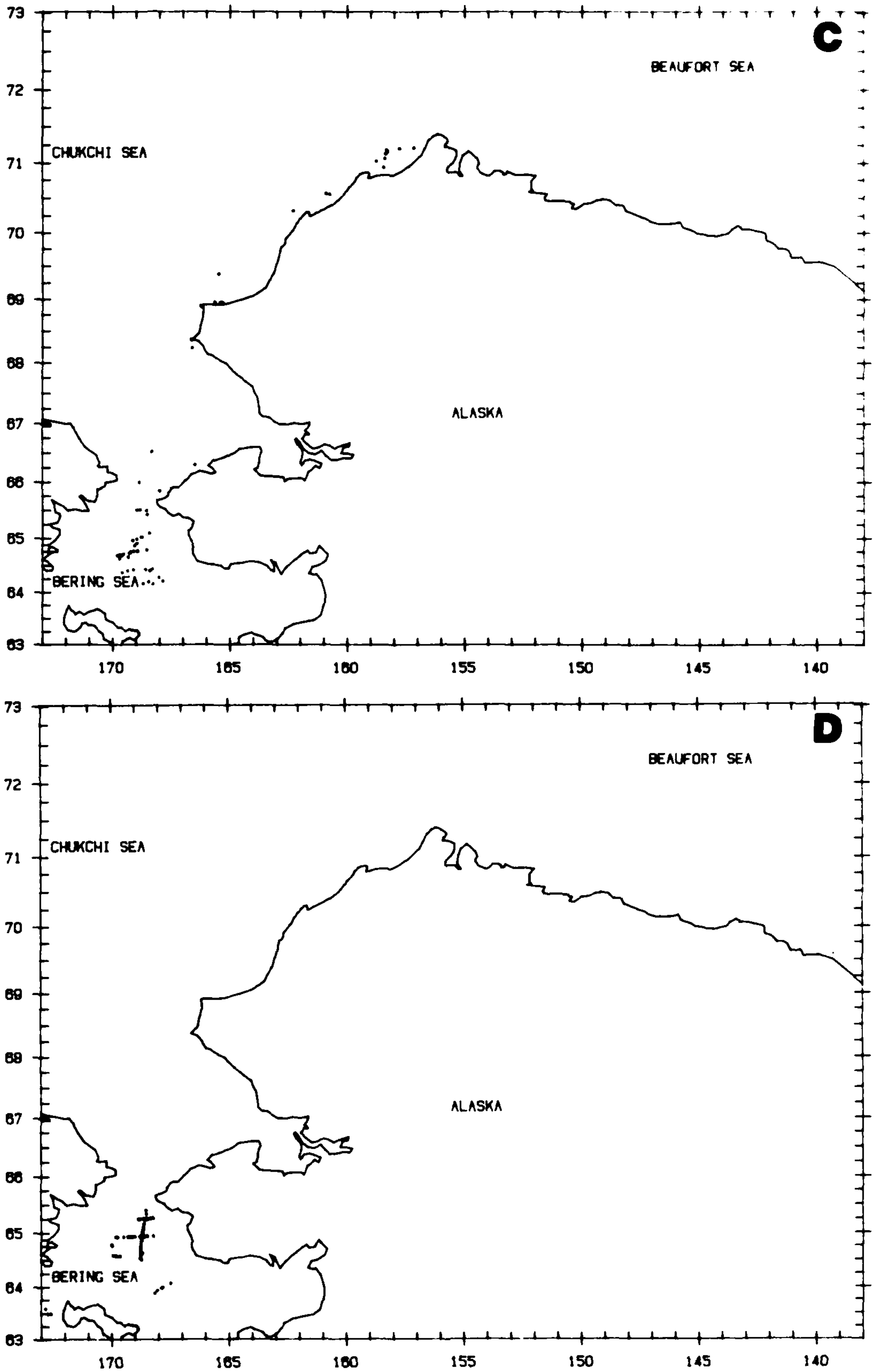

Figure 30 (contd). 62 sightings of 155 whales in October (C) and 60 sightings of 163 whales in November (D).

[illegible] grays were found in the Chirikov Basin, the southern Chukchi Sea north of the Bering Strait and along the Seward Peninsula, and in the northeastern Chukchi Sea along the coast between Pt. Hope and Pt. Barrow (Figure 30C). In November 198[illegible] [illegible] gray whales were seen on surveys conducted in the Chirikov Basin (Figure 30D).

The only gray whales reported during fall surveys in 1985 were two seen in September by researchers conducting walrus surveys for USFWS (Figure 21B). One whale was seen with three mud plumes on 22 September at 72°09.0'N, 166°17.1'W; and one was seen on 25 September at 71°07.2'N, 160°33.8'W. The whale seen on 22 September was approximately 445 km northwest of Barrow, or about twice the distance from Barrow as our farthest offshore sighting of three whales on 31 August 1984.

The highest gray whale relative abundance in the Chukchi Sea was calculated for block 13 (WPUE = 3.3), with lesser WPUE calculated for blocks 12 (WPUE = 1.82) and 17 (WPUE = 1.20) (Table 47). In the northern Bering Sea, relative abundance was highest in block 26 (20.46), with lesser values calculated for blocks 25 (10.46) and 27 (1.80).

Monthly WPUE values decreased from August to October, except in blocks 13 and 25. In block 13, WPUE was 2.49 in August, 9.45 in September, and 0.75 in October. The drop in relative abundance between September and October corresponds with reports that gray whales begin their fall migration from summer feeding grounds in mid-October (Berzin, 1984; Braham, 1984). In block 25, WPUE was 3.35 in August and 11.84 in October. This increase also may be attributed to migratory timing of southbound gray whales passing through the Bering Strait in October.

Habitat Relationships and Behavior

Of the 222 gray whales seen in fall since 1981, 92% (n = 205) were in open water or very light ($\leq$10%) ice coverage, 2% (n = 4) were in 11 to 20% ice coverage, 4% (n = 8) were in 71 to 80% coverage and 2% (n = 5) were in 81 to 90% coverage. Grays were found in water from 5 m to 62 m deep ($\bar{x}$ = 38.03, 13.67 s.d.). Whales seen along the shoreline appeared to be in water shallow enough to allow them to rest on the bottom.

Table 47. Relative abundance of gray whales (WPUE) by block, fall 1980-85.
(--) = no effort*

Month Block	Aug No.(WPUE)	Sept No.(WPUE)	Oct No.(WPUE)	Nov No.(WPUE)	Total No.(WPUE)
13	18 (2.49)	88 (9.45)	15 (0.75)	--	121 (3.30)
14	3 (1.41)	0	0	--	3 (0.24)
15	0	--	0	--	0
17	16 (2.99)	2 (0.63)	3 (0.28)	--	21 (1.20)
18	0	--	0	--	0
20	0	--	5 (0.63)	--	5 (0.43)
21	--	--	0	--	0
22	--	--	7 (1.93)	--	7 (1.93)
23	--	--	0	--	0
24	3 (1.20)	--	2 (1.21)	1(1.20)	6 (1.20)
25	12 (3.35)	--	36 (11.84)	44(19.73)	92 (10.40)
26	17 (20.48)	--	83 (17.55)	106(23.50)	206 (20.46)
27	1 (1.49)	--	--	3(1.94)	4 (1.80)
28	6 (1.71)	--	4 (2.96)	4(1.27)	14 (1.75)
29	--	--	--	0	0

*does not include whales and effort for: 17 gray whales seen in block 12 and 10 gray whales seen in unblocked areas in August, and 5 gray whales seen in unblocked areas in November.

Recruitment

Only one gray whale calf was seen in the fall over six seasons. On 17 August 1983, a calf was seen among 13 adult whales north of Point Barrow (71°26.6'N, 156°11.5'W) in 20 percent ice coverage. This was the farthest north a gray whale calf was seen.

Review Summary

1. Bowhead whales were seen in eastern Alaskan and western Canadian Beaufort Sea waters throughout August and mid-September, and were distributed across the Alaskan Beaufort Sea and into the northeastern Chukchi Sea from mid-September through October, 1979-85.

2. The annual variation in bowhead distribution in the Alaskan Beaufort Sea during the 1979-85 fall migration did not appear to be as great as that described for bowheads summering in the Canadian Beaufort Sea between 1980-84 (Richardson et al., 1985a).

3. Bowheads seen in the Alaskan Beaufort Sea in August were generally farther offshore and in deeper water than those seen in September and October.

4. There may be considerable movements of whales back and forth between the Canadian and Alaskan Beaufort Seas prior to the onset of the migration.

5. Ice coverage was negatively associated with bowhead relative abundance as calculated by WPUE ($r = -0.849$, $p \leq 0.02$) and 5-day SPUE peak (-0.568, $p \leq 0.05$). The negative correlation of ice coverage with sighting distance ($r = -0.224$, $p \leq 0.001$) likely influences these results.

6. Although there were some annual variability in observed bowhead whale distribution during the autumn 1979-85 migrations, it appears that except for 1983, the migration route may be roughly demarcated by the 20- to 40- meter isobath, and that the effects of OCS oil and gas development activities on the axis of the bowhead whale migration (as defined by median depth) are slight.

7. Although the 1983 migration route could be said to be displaced offshore compared to other years, it is not likely that this was the result of industrial activities because such activities were curtailed that year. Additionally, the migratory axis since 1983 (i.e. 1984-85) was similar to years 1979-82. There is little quantitative information available on displacement of large whales by human activities. Although gray whales (Eschrichtius robustus) were apparently displaced from a wintering breeding lagoon off Baja California, Mexico by increased ship traffic (Gard, 1974; Reeves, 1977), they returned when ship traffic abated (Bryant et al., 1984). It has been suggested that the gray whale migration has been displaced offshore by human activities, especially in the southern California Bight (Rice, 1965; Dohl and Guess, 1979), but Evans (1982) noted that this potential shift has been documented during a time when the gray whale population appears to be increasing and the apparent shift offshore may be a function of increased population size or other reasons unrelated to disturbance. Cowles et al. (1981) note that gray whales have continued to migrate along the western coast of North America despite increases in vessel traffic and other potentially disturbing activities. Additional instances where human activities have been thought to impact whale distribution include the breeding and feeding areas of north Pacific humpback whales (Megaptera novaeangliae) in Hawaii (Norris and Reeves, 1978) and Alaska (Baker et al., 1983) respectively; blue (Balaenoptera

musculus) and fin (Balaenoptera physalus) whales in the St. Lawrence river (Macfarlane, 1981); and minke whales (Balaenoptera acutorostrata) off Japan (Nishiwaki and Sasao, 1977). In all of the above cases, however, displacements have not been convincingly demonstrated (all but Bauer and Herran, 1986; reviewed by Richardson, 1983).

8. Based on 1983 results, it is likely that the 1980 migration proceeded farther offshore than aerial surveys were flown that year and went largely undetected.

9. As described in Ljungblad et al. (1986a,c) whales passing through the Alaskan Beaufort Sea stop to feed opportunistically. Feeding whales were seen in shallower water and in lighter ice coverage than whales not feeding, and so the annual availability of prey will influence somewhat the water depth and ice coverage in which whales are found. The lack of quantitative information regarding the effect of ice coverage and/or oceanographic processes along the shelf break (or ice edge) on the distribution of bowheads or their prey somewhat confounds the interpretation of data on bowhead distribution.

10. Bowhead call rate was significantly higher in September-October ($\bar{x}$ = 23.13 calls/wh-h) than in April-May ($\bar{x}$ = 9.91 calls/wh-h; $t' = 2.29$, $p < 0.05$), or August ($\bar{x}$ = 5.59 calls/wh-h; $t' = 3.17$, $p < 0.005$). There was a trend for call rates to increase with ice coverage. Bowhead call rate in 1983, a heavy ice year, was nearly an order of magnitude higher than the average of 1982, 1984-85.

11. Gray whale density in summer was greatest each year in the Chirikov Basin (0.360 whales/km^2) north of St. Lawrence Island, and along the coastal Chukchi Sea (0.261 whales/km^2).

12. The ratio of gray whale calves to all whales in summer was significantly higher in the Chukchi Sea (44/560 = 0.08) than in the northern Bering Sea (6/1983 = 0.003; $X^2 = 128.3$, $p < 0.001$). The relative abundance of gray whale calves was also significantly higher in the Chukchi Sea (0.39 calves/survey hour) than in the northern Bering Sea (0.005 calves/survey hour; $X^2 = 41.23$, $p < 0.001$) indicating that gray whales maintain patterns of reproductive class segregation on the northern range.

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APPENDIX A

AERIAL SURVEY FLIGHT CAPTIONS, SURVEY TRACKS AND SIGHTING SUMMARIES, 1985

CONTENTS

INTRODUCTION

This appendix consists of flight tracks 1 through 67, which depict aerial surveys flown over the northern Bering, eastern Chukchi, and Alaskan Beaufort Seas between mid-July and mid-October 1985. Each flight is represented by a survey track, with all marine mammal sightings plotted, and a caption describing the flight's objectives, survey conditions, and sightings. Each symbol on the flight track/sighting charts represents one sighting of one or more animals. Additionally, summary information on bowhead and gray whale sightings is presented beneath the flight caption in the tabularized format:

T#/C#	Total number of whales/total number of calves seen		
LAT/LONG	Location (latitude N/longitude W) in degrees, minutes, and tenths of minutes		
DIS	Perpendicular distance from the aircraft in meters (altitude x cotangent clinometer angle)		
CUE	Sighting cue:		
	BO = Body	MP = Mud Plumes	
	BW = Blow	DY = Display	
	SP = Splash		
BEH	Behavior:		
	SW = Swim	DY = Display	SH = Spyhop
	DI = Dive	MT = Mate	TS = Tail-Slap
	RE = Rest	FE = Feed	BR = Breach
	MI = Mill	CC = Cow-Calf	RL = Roll
		DE = Dead	NA = None
HDG	Heading in magnetic degrees		
ICE	Ice coverage in percent		
SS	Sea State (Beaufort scale)		
DEPTH	Depth in meters		

Dashes (-) indicate data were not recorded.

A monthly summary of all marine mammal sightings is provided as an overview of sighting data for the 1985 field season (Table A-1). Species abbreviations used in flight track keys are listed in Table A-1.

Table A-1. Monthly summary of all marine mammal sightings* by species.

Species	Abbr**	July	August	September	October	Total
Bowhead Whale (Balaena mysticetus)	BH	0/0	11/12	31/67	35/60	77/139
Gray Whale Eschrichtius robustus)	GW	139/705	0/0	0/0	0/0	139/705
Belukha Whale (Delphinapterus leucas)	BE	4/37	44/122	41/214	31/103	120/476
Bearded Seal (Erignathus barbatus)	BS	28/37	5/5	9/12	2/2	44/56
Ringed Seal (Phoca hispida)	RS	14/19	0/0	1/1	0/0	15/20
Walrus (Odobenus rosmarus)	WS	96/6352	0/0	0/0	0/0	96/6352
Unidentified Pinniped	PN	46/86	18/22	23/25	3/3	104/136
Polar Bear (Ursus maritimus)	PR	0/0	0/0	1/1	3/5	4/6

*The figures shown for each month represent the number of sightings/the number of individuals sighted during that period.

**Abbreviations are those used in flight track legends.

METHODS

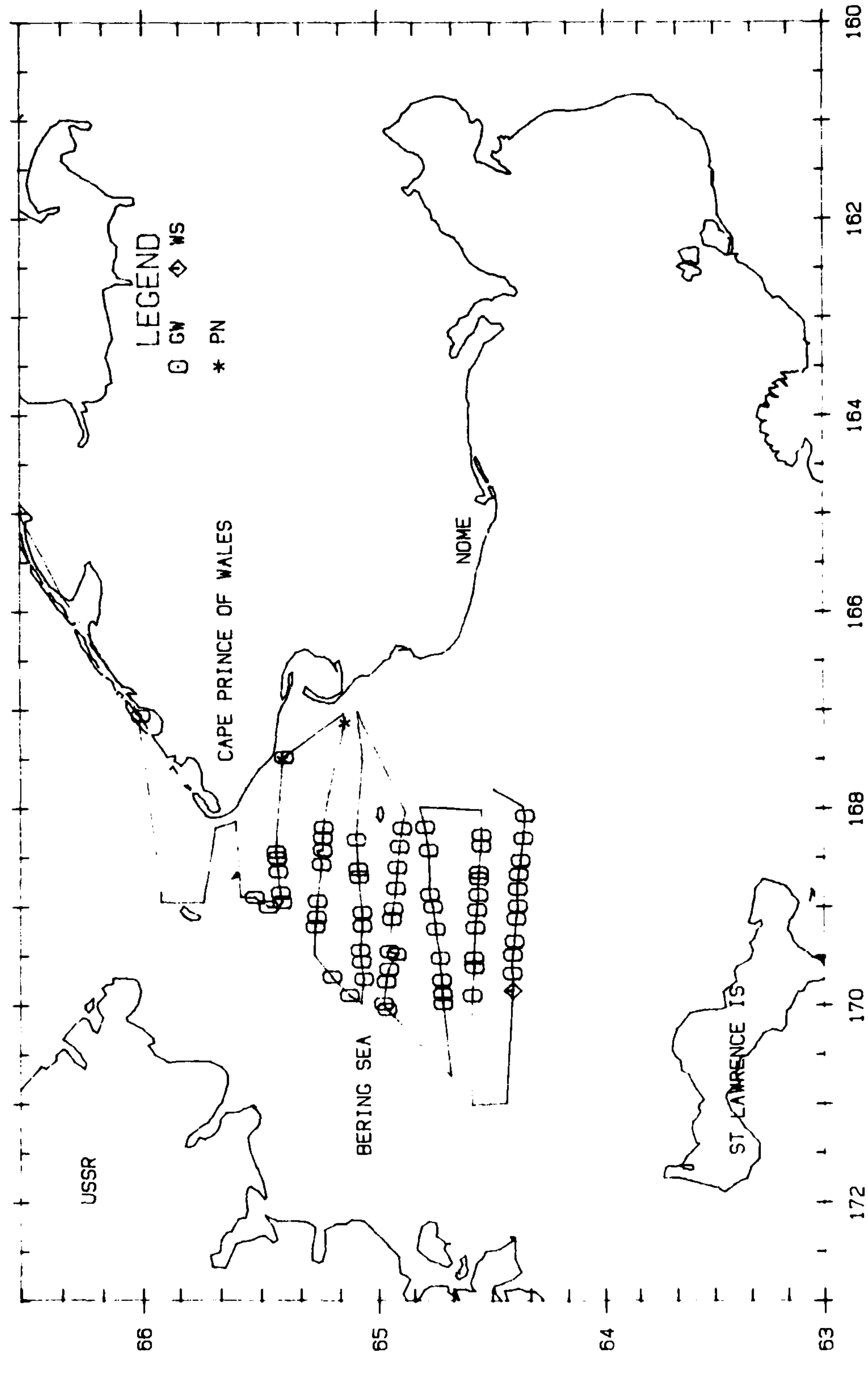
Maps were prepared using a series of computer programs consisting of BASIC subroutines implemented on a Hewlett-Packard (HP 85) microcomputer connected to a HP 7470A printer/plotter. The coastlines for each map, digitized on a HP 9111A graphics tablet, were formatted to examine the principal study areas (i.e., northern Bering Sea, eastern Chukchi Sea, and the Alaskan Beaufort Sea). As a result, a comparison of flight tracks for a given study area can be made on a visual basis over the period of the field season to evaluate ongoing patterns of the animal distribution and aircraft coverage. Each map shows the flight track as a line drawn through position updates recorded on the aircraft computer system. Each animal sighting is marked with a species symbol on the flight track plot. Additional summary information provided by the computer log is reflected in the flight captions and was used as a double check on total number of sightings of bowhead whales and the distances traveled on transect legs.

SUMMER

Flight 1: 17 July 1985

Flight was a transect survey of blocks 25 and 26. Weather was clear with unlimited visibility. Sea state ranged from Beaufort 02 to 03, and there was no ice. Four hundred seventy-eight gray whales, including 2 calves, were seen. Many were sighted with mud plumes and considered feeding. Unidentified pinnipeds and a walrus were also seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	66°00.5'	167°03.3'	—	BO	RE	180	0	B1	15
11/0	65°31.5'	168°54.0'	—	BW	FE	--	0	B3	59
9/0	65°28.1'	168°59.8'	--	BO	FE	—	0	B3	59
4/0	65°24.6'	168°57.0'	—	MP	FE	--	0	B3	59
1/0	65°25.0'	168°51.3'	--	MP	FE	190	0	B3	59
3/0	65°25.7'	168°38.3'	384	MP	FE	--	0	B3	60
3/0	65°26.0'	168°30.0'	653	MP	FE	—	0	B3	60
9/0	65°26.2'	168°26.2'	384	MP	FE	—	0	B3	60
1/0	65°24.1'	167°28.7'	653	BO	SW	270	0	B1	18
8/0	65°14.1'	168°11.5'	1027	BW	FE	--	0	B1	40
15/0	65°14.3'	168°17.9'	--	BO	FE	--	0	B1	40
7/0	65°14.4'	168°25.5'	1256	MP	FE	--	0	B1	48
7/0	65°14.7'	168°34.1'	357	BW	FE	—	0	B1	48
4/0	65°15.7'	168°56.6'	981	BW	SW	--	0	B1	55
1/0	65°15.9'	169°06.4'	1191	BW	SW	--	0	B1	51
1/0	65°16.3'	169°12.2'	1256	MP	FE	170	0	B1	51
1/0	65°12.0'	169°42.6'	223	BW	FE	110	0	B2	44
3/0	65°07.5'	169°53.8'	357	BW	SW	120	0	B2	51
7/0	65°03.8'	169°43.8'	792	BO	FE	--	0	B3	44
4/0	65°04.4'	169°33.2'	—	BW	SW	--	0	B3	46
4/0	65°04.8'	169°26.3'	—	BO	FE	--	0	B3	46
1/0	65°04.2'	169°11.4'	761	BO	SW	10	0	B3	46
2/0	65°04.2'	169°03.1'	653	BW	SW	180	0	B3	46
1/0	65°05.1'	168°41.5'	2594	MP	FE	—	0	B3	49
5/0	65°05.3'	168°36.7'	2594	BW	SW	330	0	B3	48
2/0	65°05.7'	168°18.7'	704	BW	SW	--	0	B3	48
11/0	64°52.9'	168°12.0'	384	BW	FE	--	0	B1	31
8/0	64°53.6'	168°23.3'	860	BW	FE	--	0	B1	42
5/0	64°54.2'	168°35.8'	412	BW	FE	--	0	B1	42
1/0	64°54.5'	168°48.7'	1981	BW	FE	--	0	B1	48
4/0	64°55.2'	169°01.0'	213	BO	RE	--	0	B1	48
10/0	64°55.6'	169°07.4'	—	BW	FE	—	0	B1	48
125/1	64°56.3'	169°27.1'	—	MP	FE	--	0	B1	46
17/0	64°54.5'	169°28.8'	—	BW	FE	--	0	B1	60
5/0	64°56.3'	169°38.0'	—	BW	FE	--	0	B1	46
5/0	64°57.0'	169°45.6'	825	BW	FE	—	0	B1	42
3/0	64°57.7'	169°59.0'	--	MP	FE	--	0	B1	42
1/0	64°56.9'	170°02.4'	1077	BW	FE	--	0	B2	42
3/0	64°42.6'	169°58.6'	2152	MP	FE	--	0	B3	46
1/0	64°42.7'	169°53.0'	825	BW	SW	260	0	B3	46
5/0	64°42.9'	169°44.5'	2594	MP	FE	--	0	B3	46
8/0	64°43.4'	169°31.1'	653	BO	SW	180	0	B3	46
5/0	64°44.5'	169°13.4'	2887	BW	SW	--	0	B3	46
1/0	64°45.1'	168°59.8'	508	BO	RE	200	0	B3	46
1/0	64°45.9'	168°52.3'	233	BO	SW	340	0	B3	46
3/0	64°46.3'	168°25.3'	320	BO	SW	180	0	B3	44
1/0	64°47.1'	168°11.3'	704	BO	FE	55	0	B3	38
4/0	64°32.6'	168°16.5'	264	BO	RE	—	0	B1	37
5/0	64°32.7'	168°22.8'	1328	BW	FE	--	0	B1	42
1/0	64°33.4'	168°39.1'	1132	BW	SW	--	0	B1	42
6/0	64°33.4'	168°42.9'	264	BO	SW	160	0	B1	44
5/0	64°33.4'	168°52.8'	--	BO	FE	—	0	B1	44
8/0	64°33.8'	169°01.8'	—	MP	FE	--	0	B1	42
5/0	64°34.3'	169°12.7'	—	MP	FE	--	0	B1	42
7/0	64°34.7'	169°31.4'	--	MP	FE	--	0	B1	44
15/0	64°34.5'	169°36.9'	--	BO	FE	--	0	B1	44
2/0	64°35.1'	169°54.1'	—	BW	SW	--	0	B1	35
12/0	64°24.6'	169°40.4'	--	BW	SW	--	0	B2	37
8/0	64°24.6'	169°29.1'	860	BW	SW	--	0	B2	37
12/0	64°24.1'	169°20.8'	565	MP	FE	--	0	B2	37
1/0	64°23.6'	169°07.2'	345	BO	SW	--	0	B2	38
12/0	64°23.2'	168°59.4'	—	BW	SW	--	0	B2	40
9/0	64°23.2'	168°49.0'	—	BW	SW	--	0	B2	40
6/0	64°23.0'	168°40.1'	--	BW	SW	--	0	B2	40
5/0	64°22.5'	168°31.6'	—	BW	SW	--	0	B2	42
14/1	64°21.7'	168°18.1'	653	BW	SW	--	0	B2	37
3/0	64°21.2'	168°04.4'	1132	BO	SW	--	0	B2	37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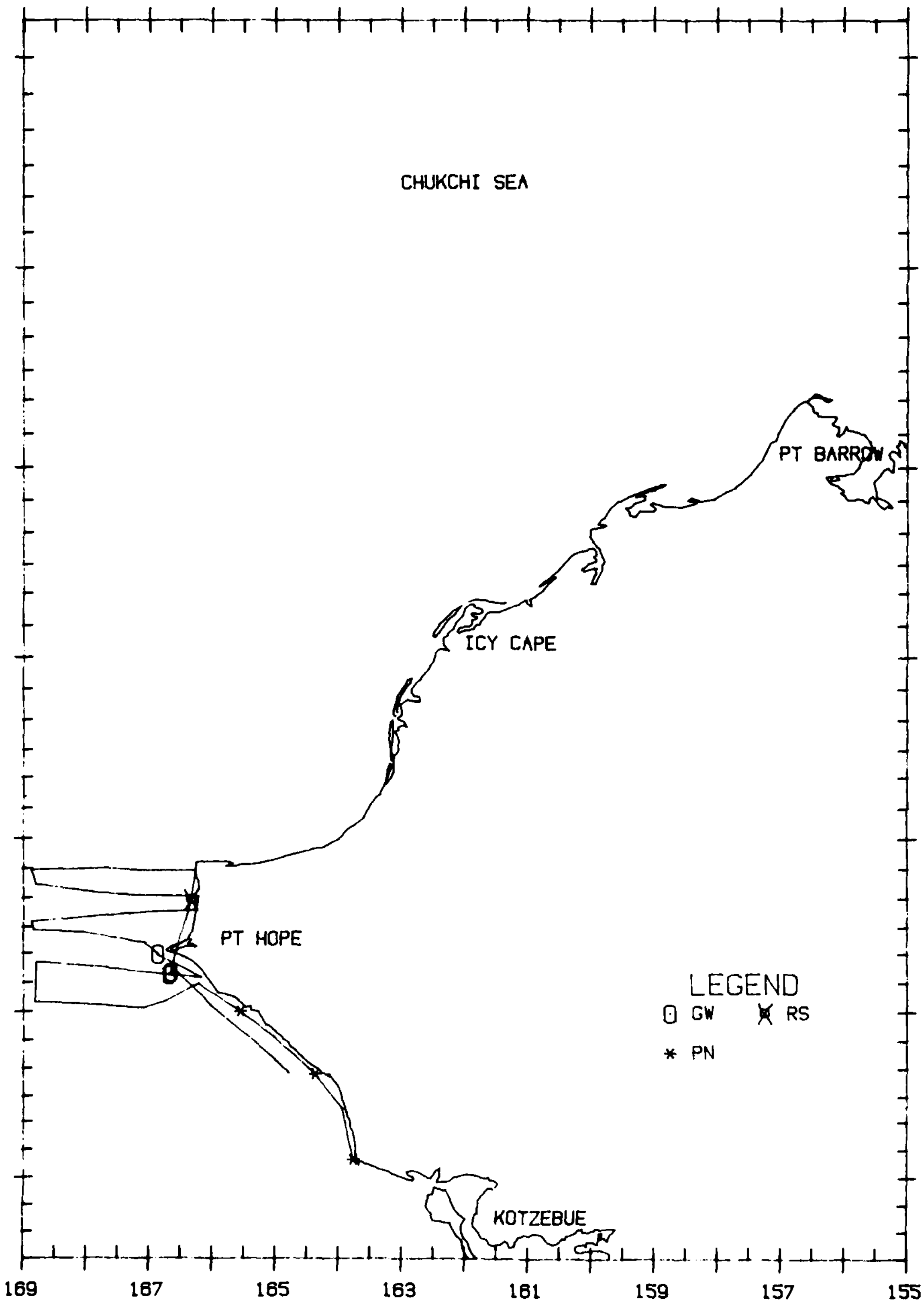
Flight 2: 18 July 1985

Flight was a transect survey of block 22 and a coastal search survey to and from the block. Weather was clear with unlimited visibility. Ice coverage varied from 0-to 40-percent broken floe and sea state ranged from Beaufort 01 to 03. Sixteen gray whales, including 5 calves, were seen swimming, feeding, and resting south of Pt. Hope. Ringed seals and unidentified pinnipeds were also seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
5/0	68°13.1'	166°41.0'	1981	BW	FE	330	0	B1	33
6/3	68°20.1'	166°51.8'	--	BO	CC	--	5	B1	13
5/2	68°13.8'	166°39.6'	--	BO	FE	--	0	B2	18



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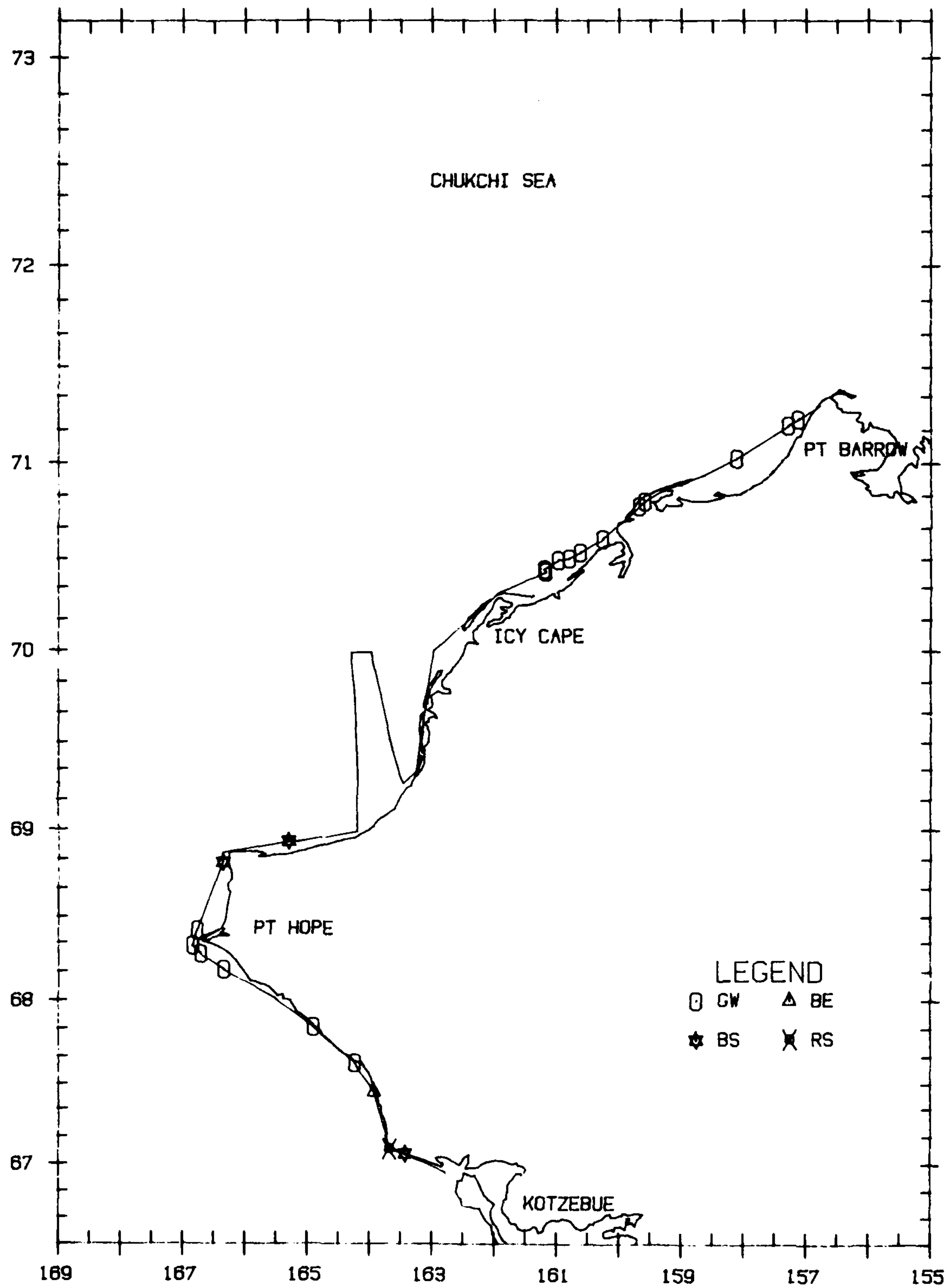
Flight 3: 19 July 1985

Flight was a transect survey of the eastern one-half of block 20 and a coastal search survey transit to Pt. Barrow. Weather was clear with unlimited visibility. Ice coverage ranged from 1-to 50-percent broken floe near-shore to 0 percent offshore in block 20 and sea state varied from Beaufort 01 near-shore to 04 offshore. In the northern Chukchi Sea, 95 percent broken floe ice existed 100 km offshore at Icy Cape, 60 km offshore at Wainwright and 20 km offshore at Pt. Barrow. Sea state in the near-shore open water corridor was Beaufort 03. Fifty seven gray whales were seen. Seventeen, including one calf, were seen swimming and feeding south of Pt. Hope. The remaining 40, including 4 calves, were seen swimming and feeding along the coast between Icy Cape and Pt. Barrow. Belukhas and bearded and ringed seals were also seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
2/0	67°37.6'	164°14.2'	457	BO	SW	110	0	B1	5
1/0	67°50.4'	164°53.9'	264	BO	DI	250	0	B1	5
6/0	68°10.7'	166°20.4'	--	BO	SW	--	0	B3	18
2/0	68°16.1'	166°42.4'	--	BO	SW	--	0	B3	18
5/1	68°18.9'	166°50.1'	--	BO	RE	--	0	B3	18
1/0	68°24.2'	166°45.5'	585	BO	RE	140	20	B1	13
8/0	70°24.6'	161°09.6'	--	BW	FE	--	0	B3	11
9/1	70°25.3'	161°10.9'	--	BW	FE	--	0	B3	18
3/1	70°28.1'	160°57.4'	--	BO	FE	--	0	B3	18
3/0	70°30.1'	160°46.7'	761	MP	FE	--	0	B3	20
1/0	70°32.0'	160°36.0'	981	BW	SW	180	0	B3	18
1/0	70°36.3'	160°14.2'	253	BO	RE	--	0	B3	18
2/0	70°46.5'	159°40.0'	--	BW	SW	180	0	B3	5
6/0	70°48.0'	159°34.4'	--	BW	SW	--	0	B3	5
2/0	71°01.4'	158°05.8'	457	BO	FE	150	5	B3	20
3/1	71°11.2'	157°16.2'	1256	MP	FE	--	5	B3	18
2/1	71°13.0'	157°06.5'	176	MP	FE	--	5	B3	18



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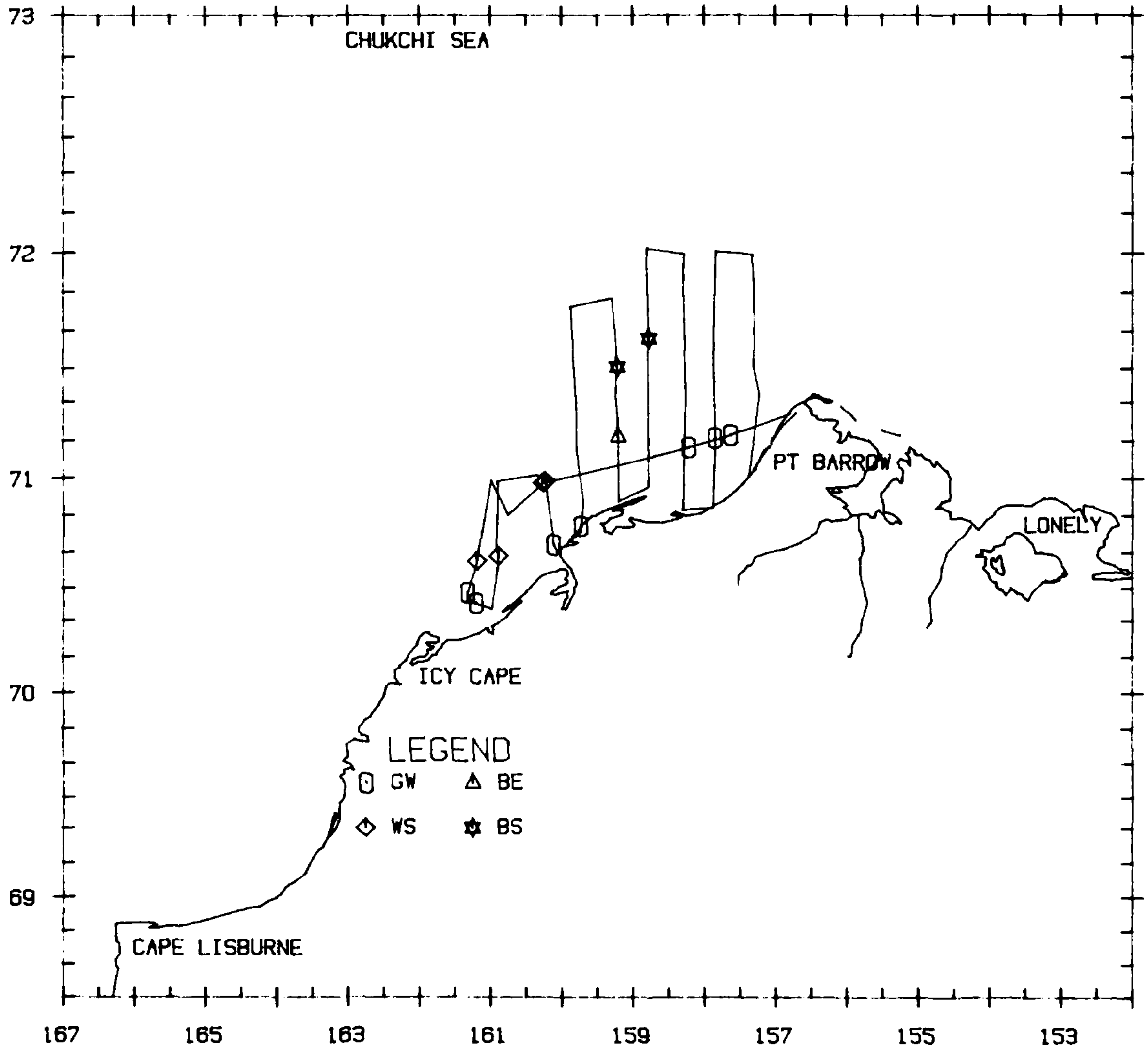
Flight 4: 20 July 1985

Flight was a transect survey of block 13 and the eastern one-half of block 17. Weather was overcast with unlimited visibility, except in the southwestern corner of block 13 where heavy fog prevailed. Ninety-nine percent broken floe ice existed in the northern two-thirds of block 13 and northern half of block 17, and open water existed south of there in the near-shore areas. Sea state ranged from Beaufort 03 in open water areas to 00 in areas with heavy ice. Twelve gray whales were seen swimming and feeding. Belukhas, walrus, and bearded seals were also seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°10.6'	157°51.0'	522	BO	SW	20	0	B2	42
1/0	70°47.2'	159°44.1'	--	BO	SW	--	30	B2	18
2/0	70°42.1'	160°06.9'	339	BO	SW	350	5	B2	18
5/0	70°24.7'	161°12.1'	191	BO	FE	130	0	B3	11
1/0	70°27.6'	161°19.3'	238	BO	SW	110	0	B4	18
1/0	71°08.3'	158°12.5'	327	BO	FE	210	5	B3	20
1/0	71°11.5'	157°37.3'	1138	BW	FE	45	5	B3	38



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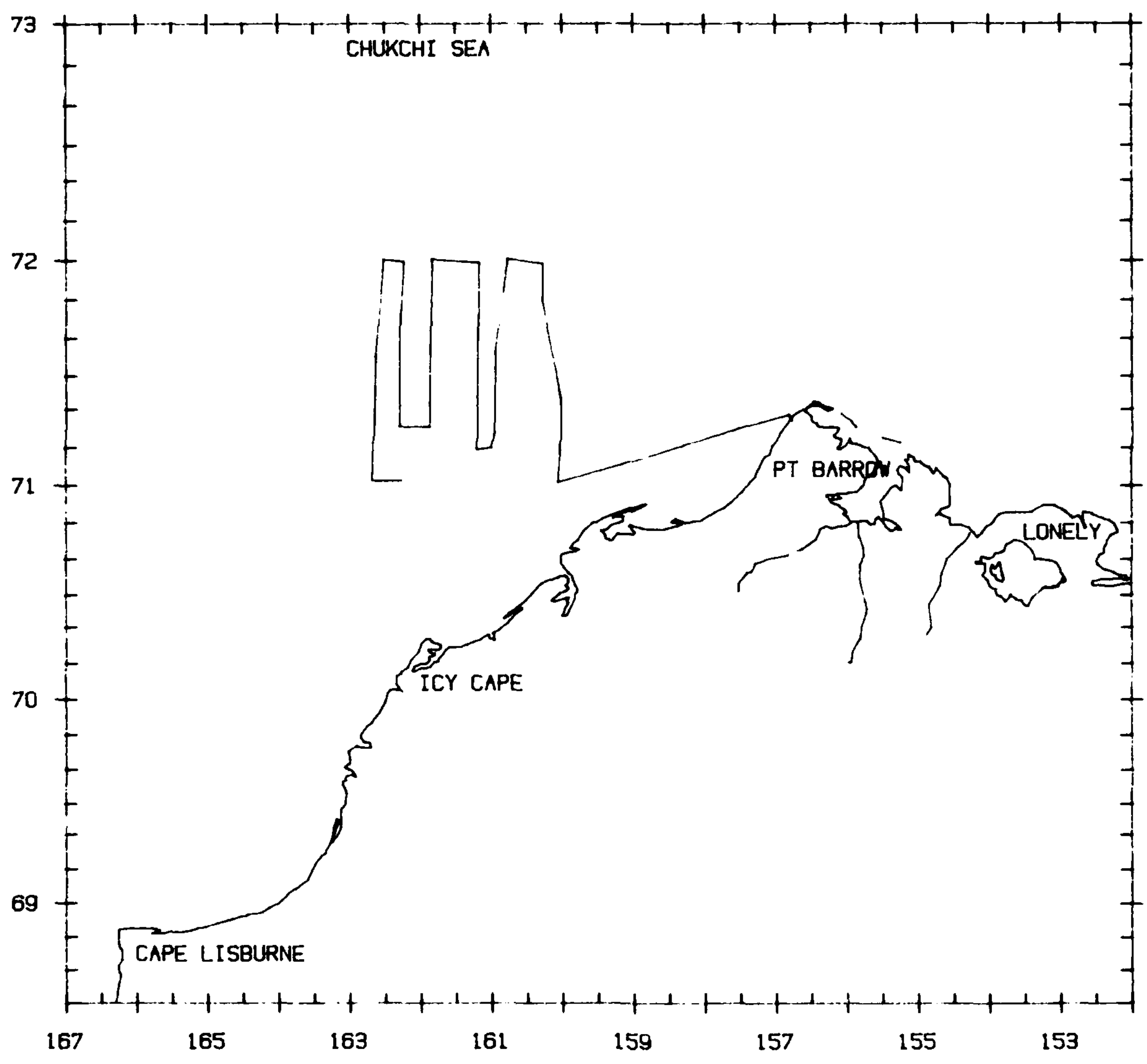
Flight 5: 21 July 1985

Flight was a transect survey of block 14. Weather was clear with unlimited visibility over the ice, and dense fog with unacceptable visibility over open water areas. Sea state in block 14 was Beaufort 00, with 95 to 99 percent broken floe ice coverage. In the near-shore open water corridor, sea state was Beaufort 03. No marine mammals were sighted.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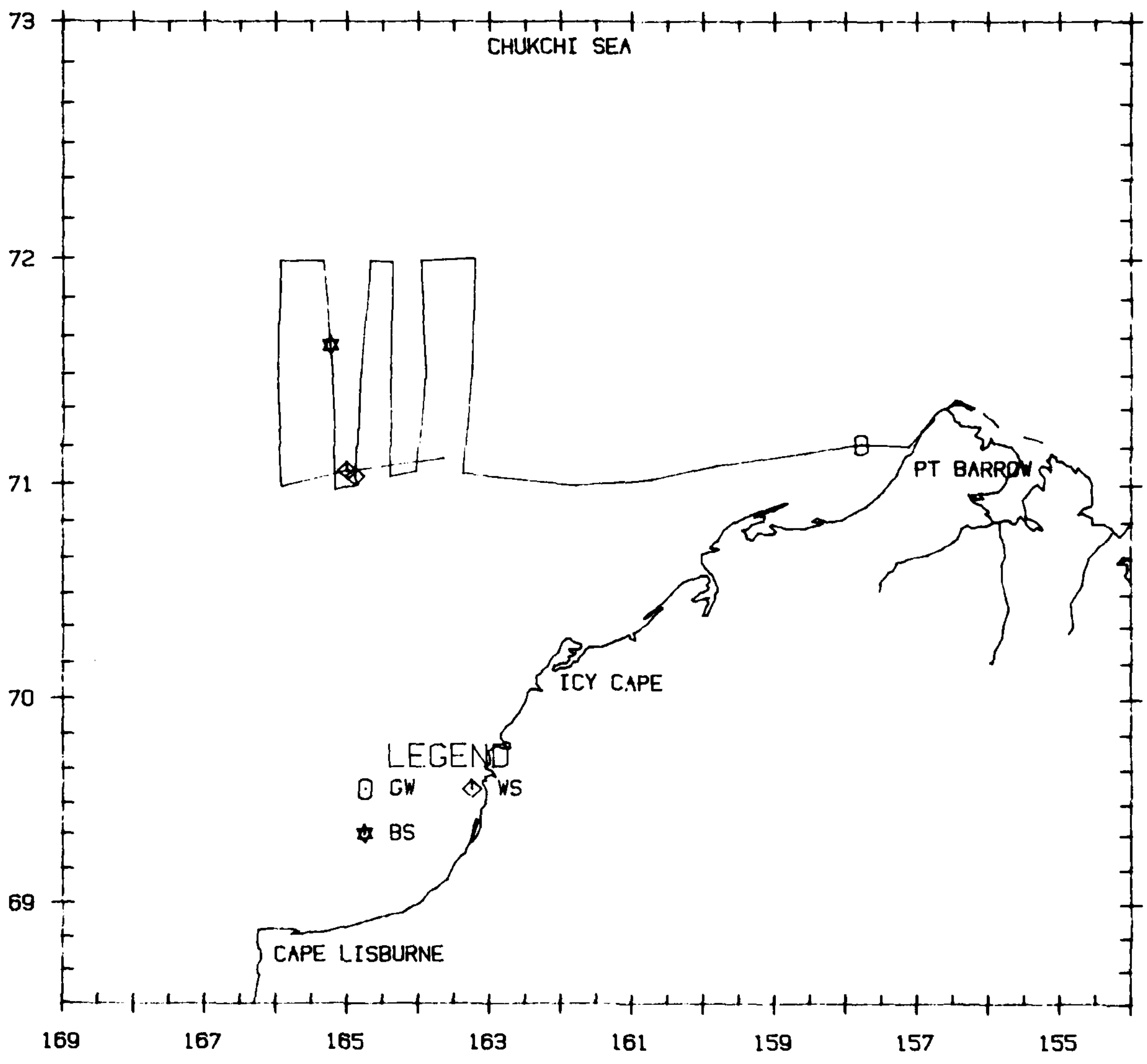
Flight 6: 22 July 1985

Flight was a transect survey of block 15, after dense fog precluded surveying blocks 17 and 18. Weather was clear with unlimited visibility over the ice, and dense fog with unacceptable visibility over open water areas. Block 15 was completely covered with 99 percent broken floe ice. Sea state was Beaufort 00 to 01 in heavy ice areas and Beaufort 03 in the open water corridor. One gray whale was seen feeding. Walrus and a bearded seal were also seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°10.6'	157°46.9'	607	MP	FE	--	10	B1	42



CHUKCHI SEA
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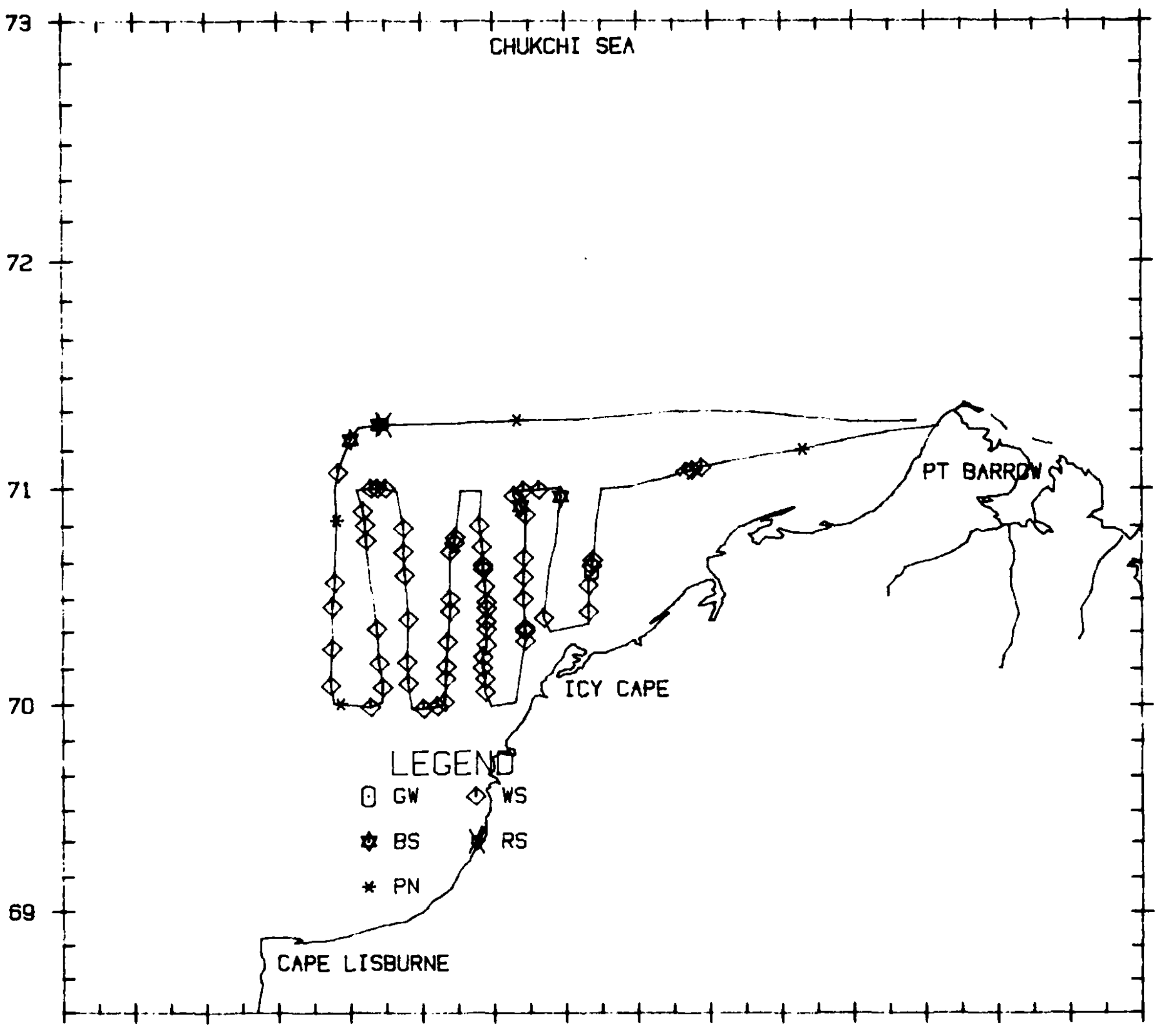
Flight 7: 23 July 1985

Flight was a transect survey of the western one-half of block 17 and all of block 18. Weather was overcast with unlimited visibility. Ice coverage varied from 0 to 99 percent broken floe in block 17, and 0 to 60 percent broken floe in block 18. Sea state ranged from Beaufort 02 in open water areas to 00 in heavy ice. Two gray whales were seen feeding. Walrus, bearded and ringed seals, and unidentified pinnipeds were also seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
2/0	70°38.4'	161°37.7'	1542	BO	FE	240	0	B1	22



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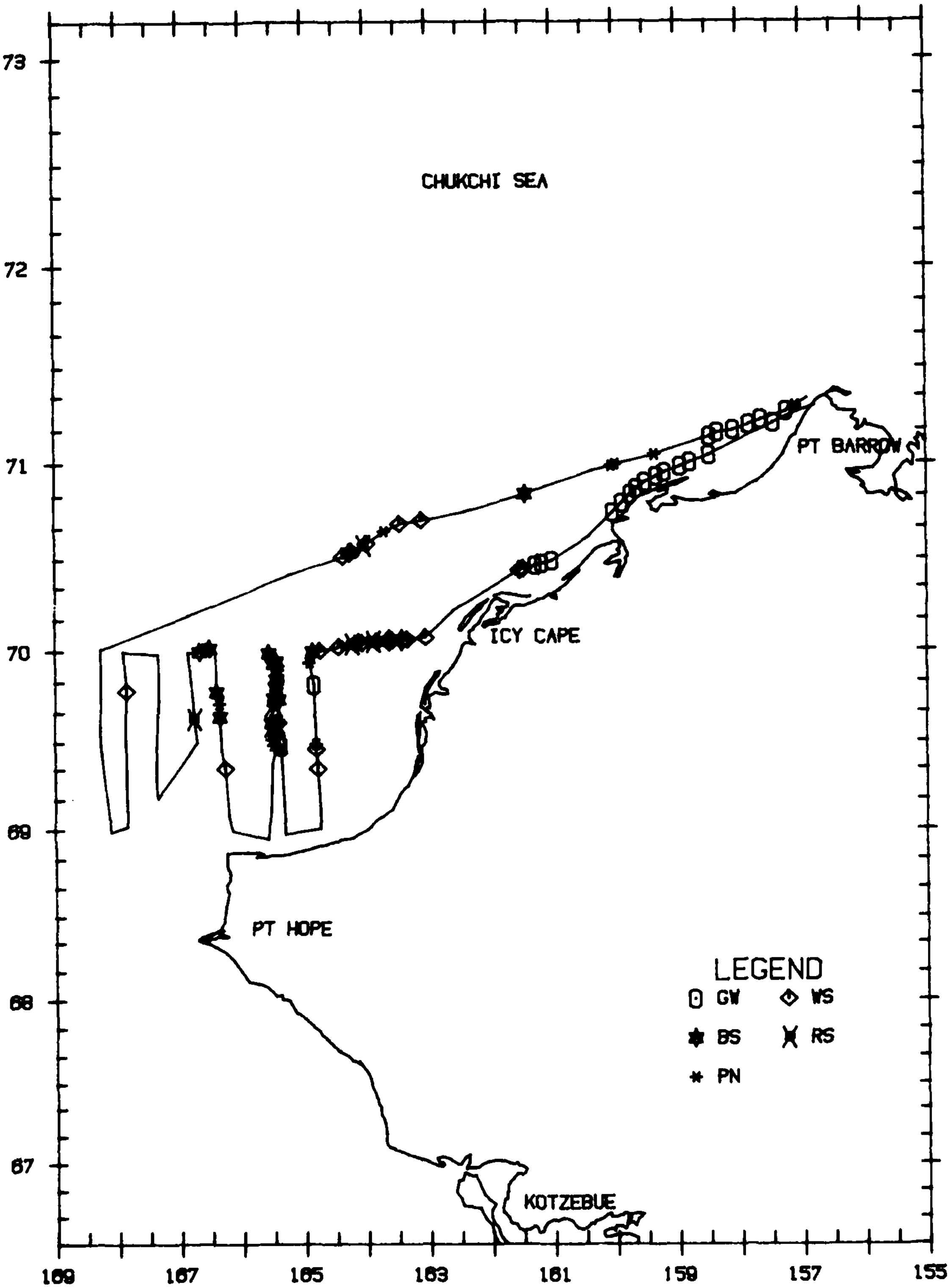
Flight 8: 24 July 1985

Flight was a transect survey of the western one-half of block 20 and all of block 21. Weather was mostly clear with unlimited visibility, except in the southeast corner of block 21, where low fog caused transect lines to be truncated. Ice coverage varied from 0 to 30 percent broken floe near-shore to 0 percent in offshore areas. Sea state ranged from Beaufort 00 to 01. Seventy-six gray whales were seen along the coastline. Walrus, bearded and ringed seals, and unidentified pinnipeds were also seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°11.8'	157°26.2'	245	MP	FE	--	1	B1	38
2/0	71°02.1'	158°28.4'	2274	MP	FE	--	1	B1	18
1/0	71°00.0'	158°47.0'	1314	BW	SW	30	0	B1	18
10/0	70°58.7'	158°56.6'	--	BW	FE	--	0	B1	18
3/0	70°56.9'	159°11.8'	1496	BW	SW	30	0	B1	27
2/0	70°55.8'	159°19.7'	631	BW	RE	200	0	B1	27
5/0	70°53.9'	159°30.7'	--	BO	SW	30	0	B1	18
3/0	70°51.9'	159°39.0'	1496	BW	SW	--	0	B1	18
4/0	70°50.1'	159°44.8'	993	BW	FE	--	0	B1	26
5/0	70°47.4'	159°52.8'	--	BO	FE	--	0	B1	18
2/0	70°44.5'	160°01.3'	1707	BW	SW	--	0	B1	18
4/0	70°28.0'	161°00.4'	6540	BO	FE	--	0	B1	18
4/0	70°27.2'	161°10.3'	1328	MP	FE	--	0	B1	18
2/0	70°26.5'	161°16.4'	357	BO	RE	--	0	B1	18
1/0	69°49.0'	164°50.8'	1648	BW	SW	--	0	B0	22
1/0	69°27.4'	165°22.9'	653	BO	RE	30	0	B0	27
3/0	69°31.4'	165°24.8'	--	MP	FE	220	0	B0	27
3/0	69°28.8'	165°24.6'	--	BW	FE	--	0	B0	27
1/0	71°07.7'	158°27.8'	792	BO	SW	180	0	B1	20
5/0	71°08.9'	158°20.1'	898	BW	FE	--	0	B1	20
7/0	71°09.7'	158°04.8'	--	MP	FE	--	0	B1	20
4/0	71°11.2'	157°49.9'	2353	BW	FE	--	0	B1	42
2/0	71°12.8'	157°38.1'	1707	BW	FE	--	0	B1	38
1/0	71°15.3'	157°13.8'	728	MP	FE	--	0	B1	35



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CHUKCHI SEA
PT BARROW
ICY CAPE
PT HOPE
KOTZEBUE
LEGEND
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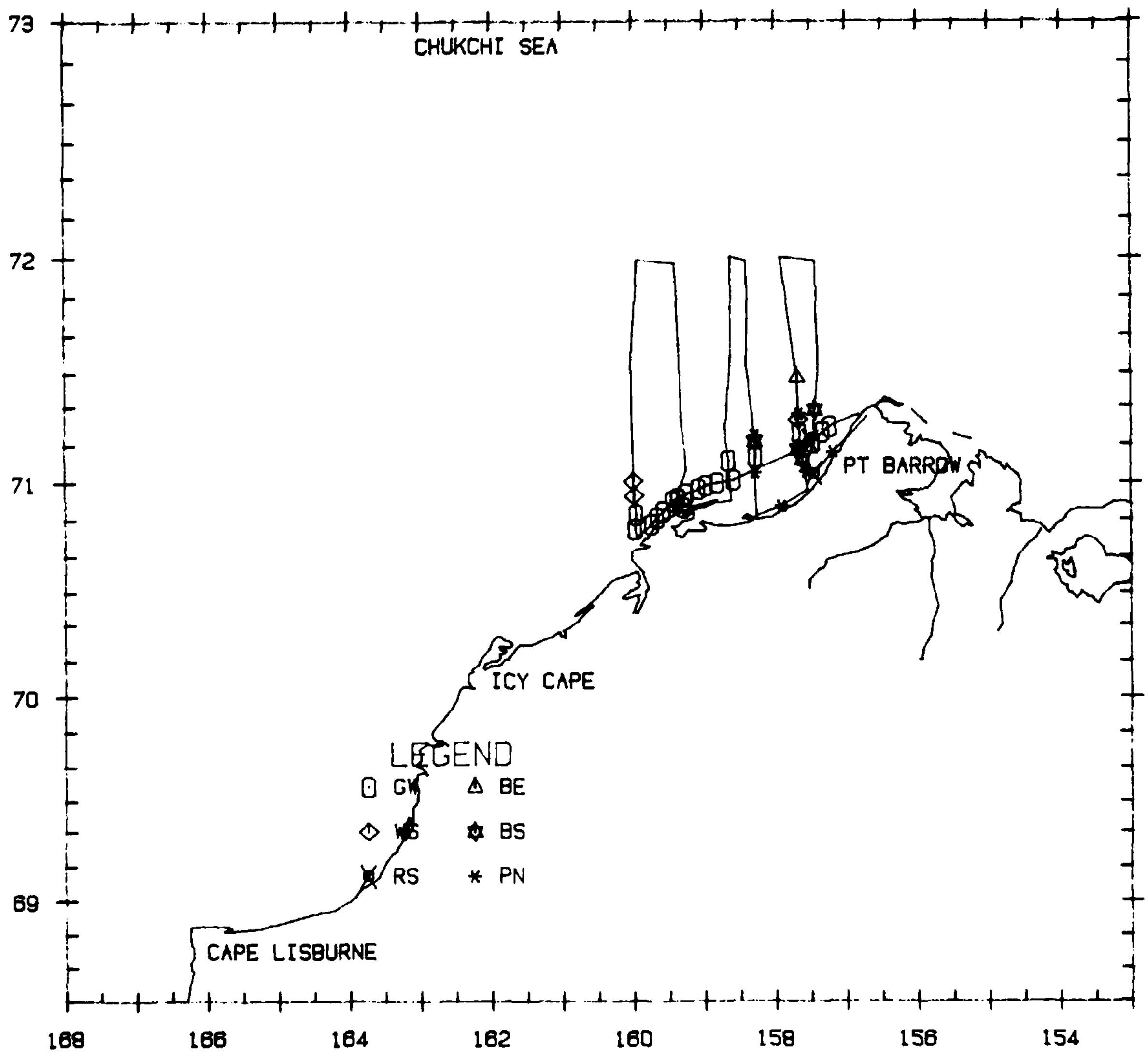
Flight 9: 25 July 1985

Flight was a transect survey of block 13. Weather was mostly overcast with unlimited visibility, with some areas of light patchy fog. Ice coverage was 0 percent in the southern half of the block and 99 percent broken floe in the northern half. Sea state ranged from Beaufort 00 to 02. Sixty-three gray whales, including five calves, were seen. One belukha, walrus, bearded and ringed seals, and unidentified pinnipeds were also seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
3/1	71°10.5'	157°28.1'	426	BO	FE	100	0	B1	38
6/2	71°13.1'	157°39.7'	1132	BO	FE	--	0	B1	38
6/0	71°06.6'	158°17.0'	1361	MP	FE	--	0	B1	20
1/0	71°05.7'	158°39.9'	948	BO	SW	170	5	B1	20
2/0	70°53.4'	159°18.3'	546	BO	RE	30	1	B2	18
8/0	70°51.4'	159°58.1'	1546	BW	SW	--	0	B1	26
3/0	70°47.4'	159°58.9'	--	BO	SW	--	0	B1	18
1/0	70°48.7'	159°45.0'	792	MP	FE	--	0	B1	18
4/0	70°50.4'	159°40.1'	1077	BW	SW	190	0	B1	26
1/0	70°52.2'	159°34.9'	474	BO	SW	70	0	B1	18
1/0	70°54.9'	159°26.7'	201	BO	SW	210	0	B1	18
2/0	70°55.7'	159°22.4'	585	BO	SW	--	0	B1	37
2/0	70°56.9'	159°15.5'	331	BO	SW	--	0	B1	27
8/0	70°58.3'	149°04.7'	1546	BO	FE	--	0	B1	27
3/0	70°59.2'	158°58.4'	1077	BO	FE	--	0	B1	18
4/1	71°00.0'	158°49.0'	2152	BO	SW	--	0	B1	18
2/1	71°00.6'	158°35.1'	--	BO	SW	60	0	B1	18
3/0	71°13.4'	157°20.0'	1707	MP	FE	--	0	B1	18
3/0	71°14.7'	157°14.0'	1077	MP	FE	--	0	B1	18



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CHUKCHI SEA
PT BARROW
ICY CAPE
CAPE LISBURNE
LEGEND
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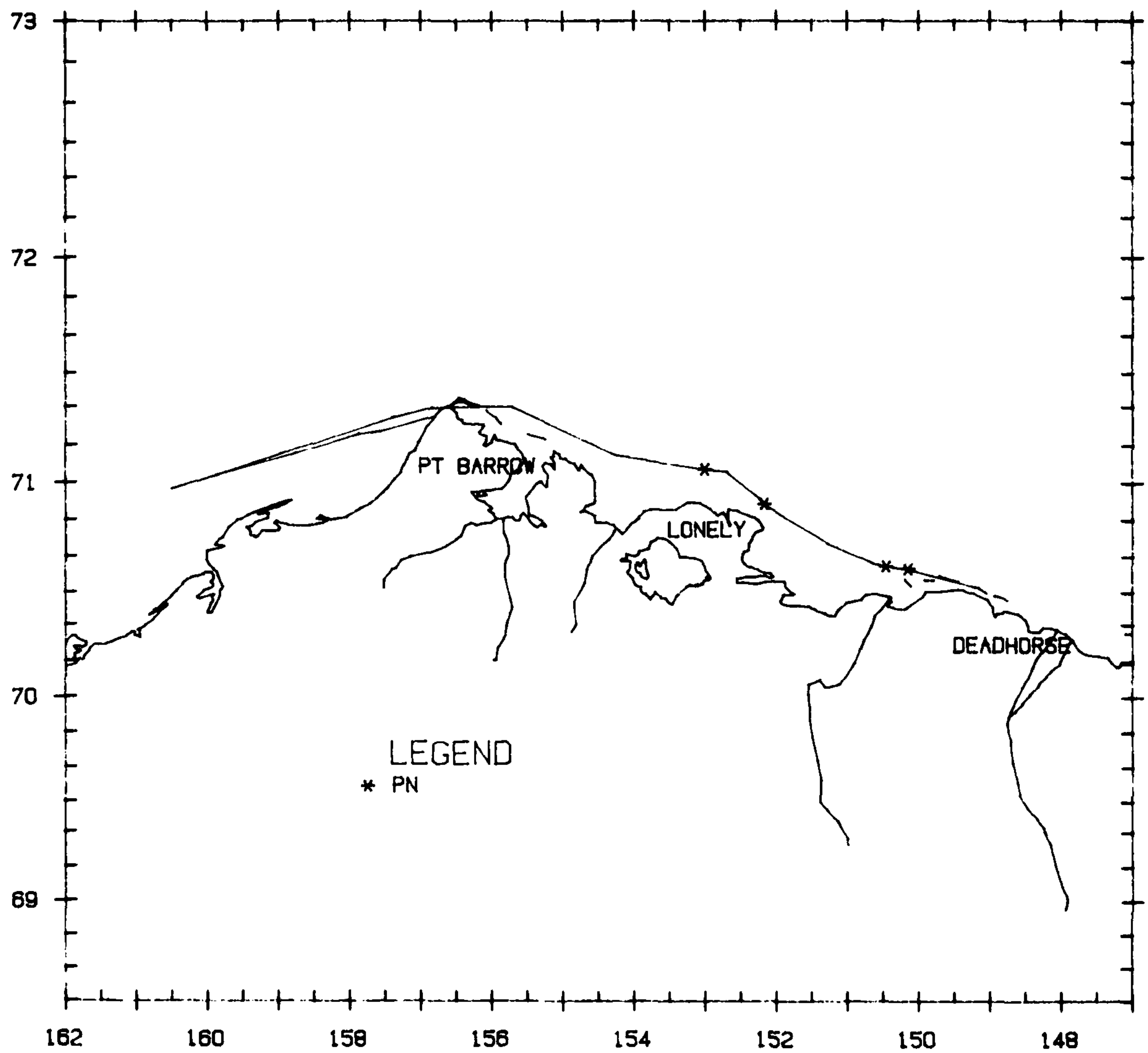
Flight 10: 26 July 1985

Flight was a coastal search survey transit to Deadhorse after heavy fog precluded any surveys in the Chukchi Sea. Weather in the Beaufort Sea was overcast with unlimited visibility. Ice coverage was 10 to 99 percent broken floe and sea state was Beaufort 00 to 01. Unidentified pinnipeds were seen.



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PT BARROW
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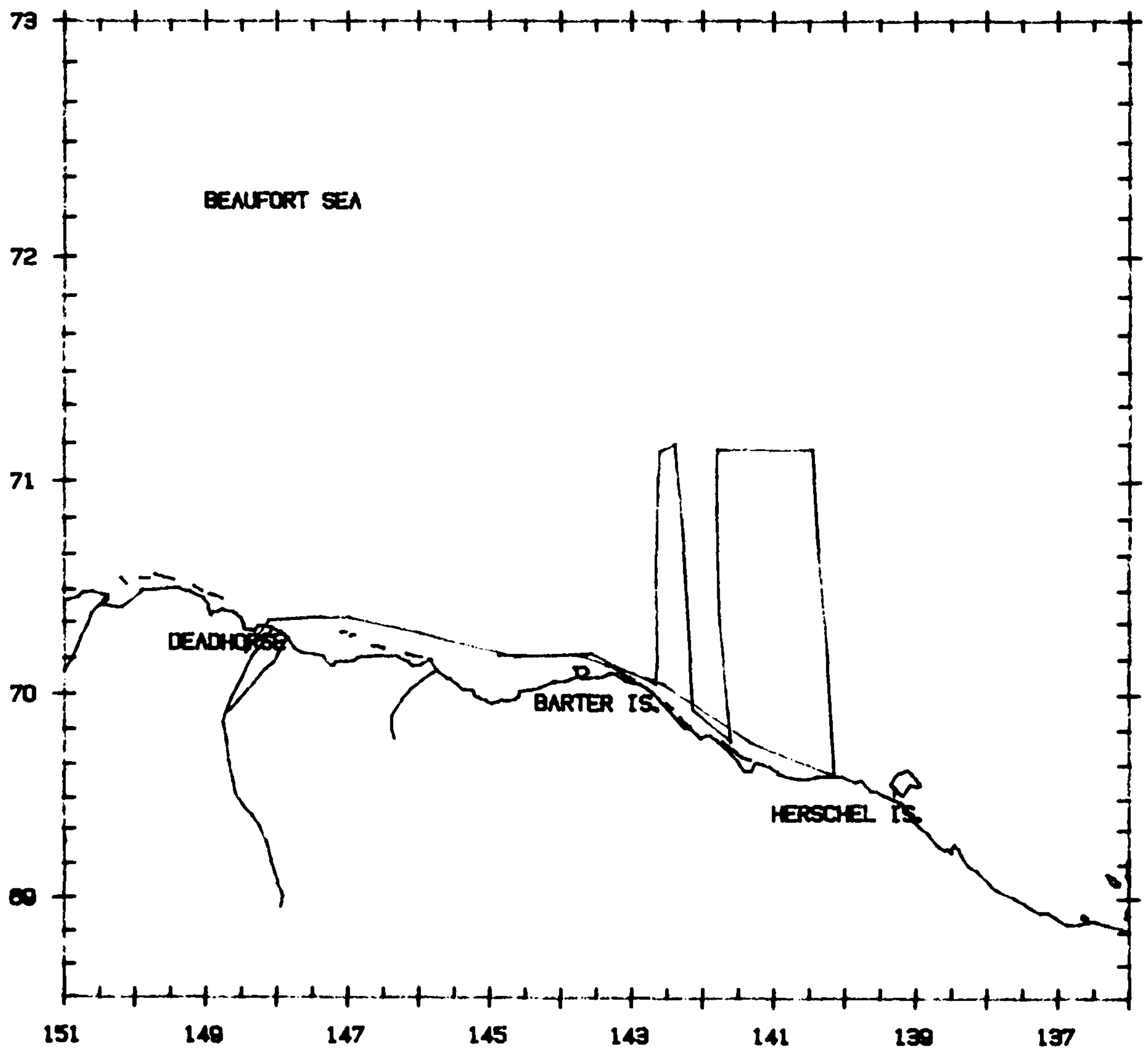
Flight 11: 28 July 1985

Flight was a transect survey of blocks 5 and 7. Weather was generally overcast with unlimited visibility,with some areas of light patchy fog. Ice coverage was 75 to 99 percent broken floe except in Camden Bay, where it was 0 to 30 percent, and inside the barrier islands, where there was no ice. Sea state was Beaufort 00 to 01. No marine mammals were sighted.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BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
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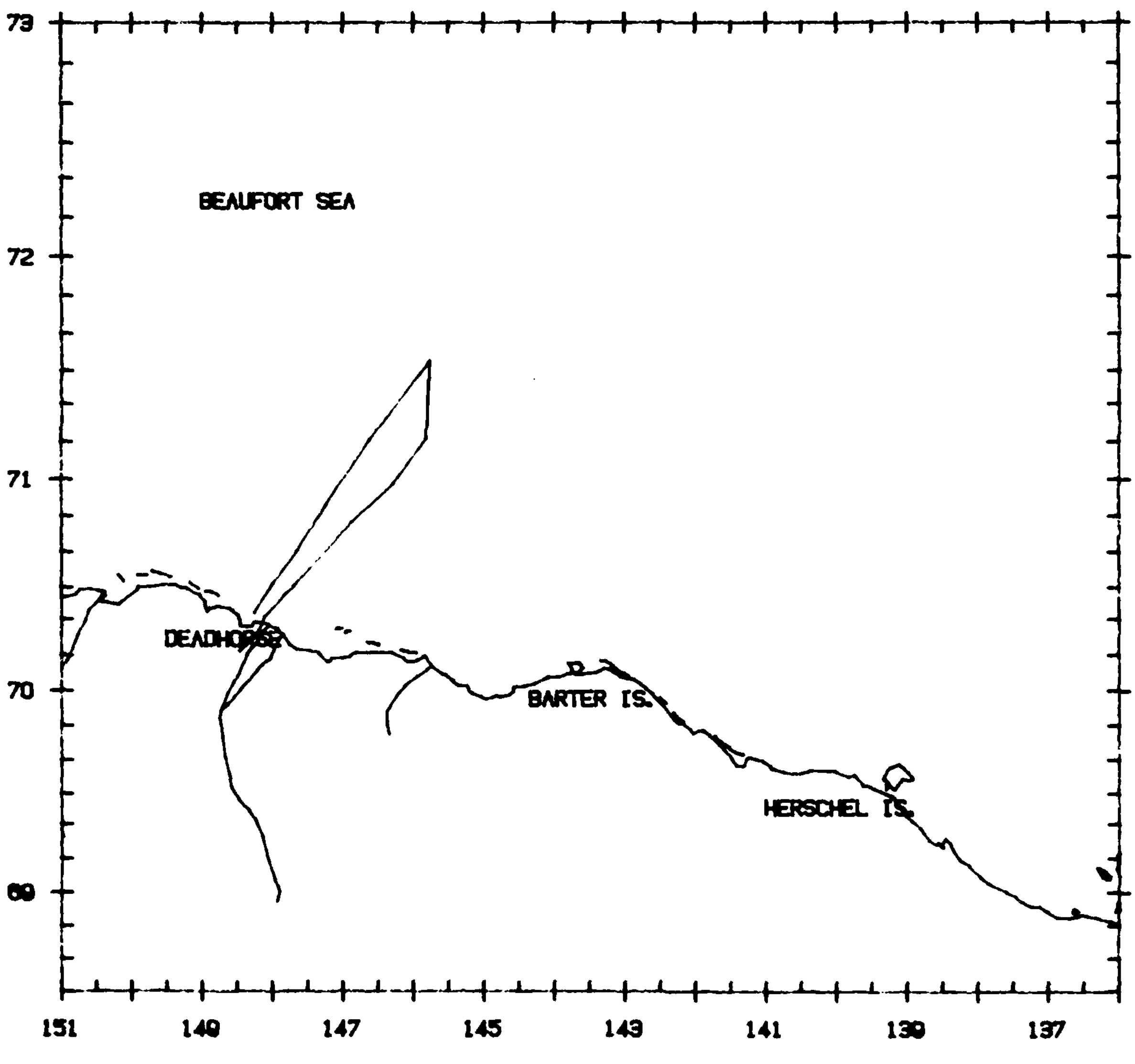
Flight 12: 29 July 1985

Flight was an aborted transect survey of block 9. Dense, low-lying fog over the entire Alaskan Beaufort Sea prevented flying in any area. Sea state was Beaufort 00, and ice was 99 percent broken floe. No marine mammals were seen.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BEAUFORT SEA
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Flight 13: 30 July 1985

Flight was a transect survey of block 9. Weather was clear with unlimited visibility. Ice coverage was 99 percent broken floe and sea state was Beaufort 00. Belukhas and a bearded seal were seen.

AD-A172 753 AERIAL SURVEYS OF ENDANGERED WHALES IN THE NORTHERN BERING EASTERN CHUKCH..(U) NAVAL OCEAN SYSTEMS CENTER SAN DIEGO CA D K LJUNGBLAD ET AL. AUG 86 NOSC/TR-1111 3/5

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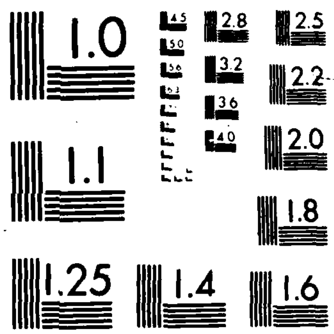
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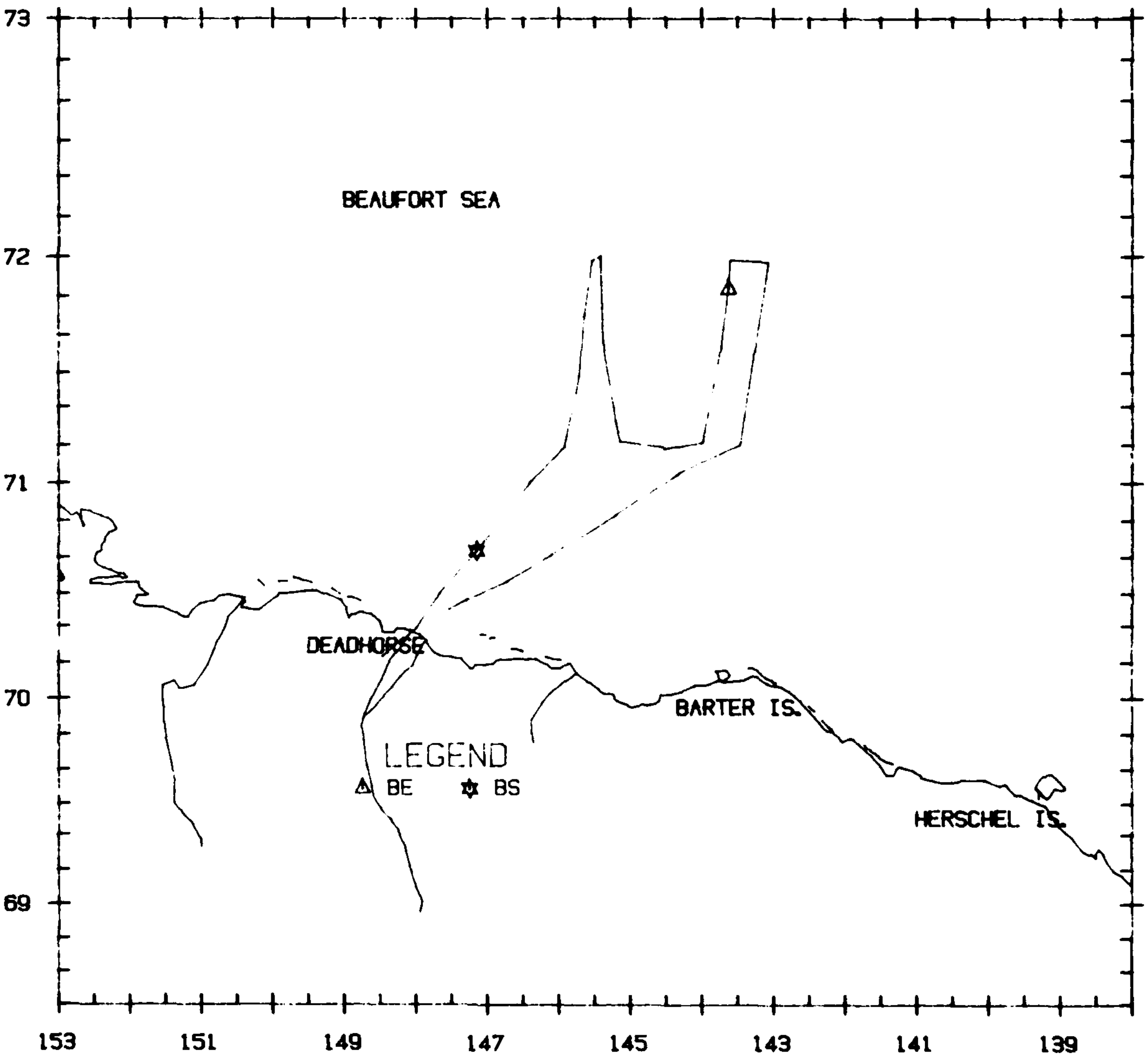

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BEAUFORT SEA
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BARTER IS.
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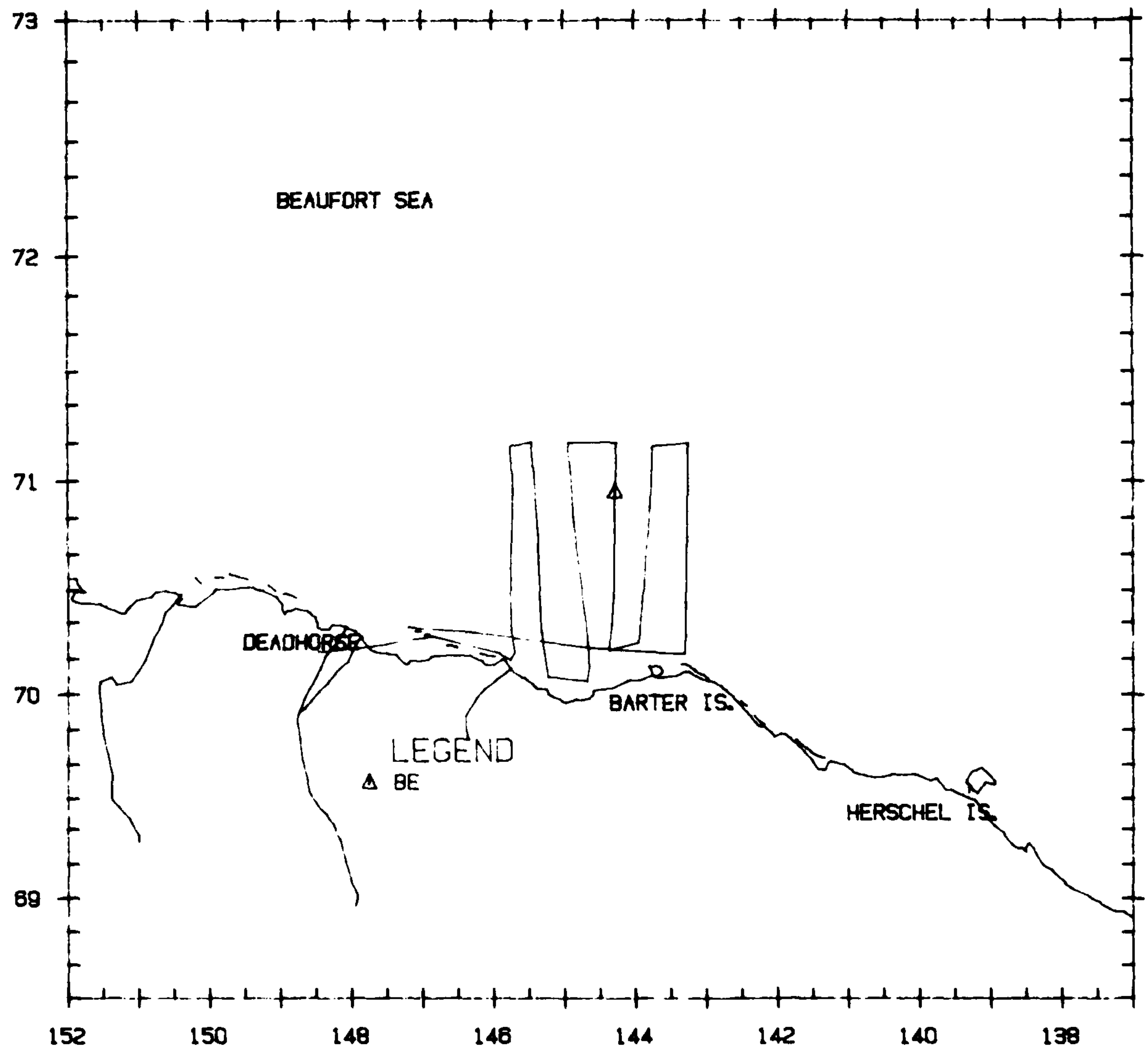
FALL

Flight 14: 2 August 1985

Flight was a transect survey of blocks 4 and 6. Weather was generally clear with unlimited visibility, except in the southeastern corner of block 4, which was covered by low-lying fog. Ice coverage was 99 percent broken floe in both blocks except inside the barrier islands. Sea state was Beaufort 00 to 01. One belukha was seen.



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BARTER IS.
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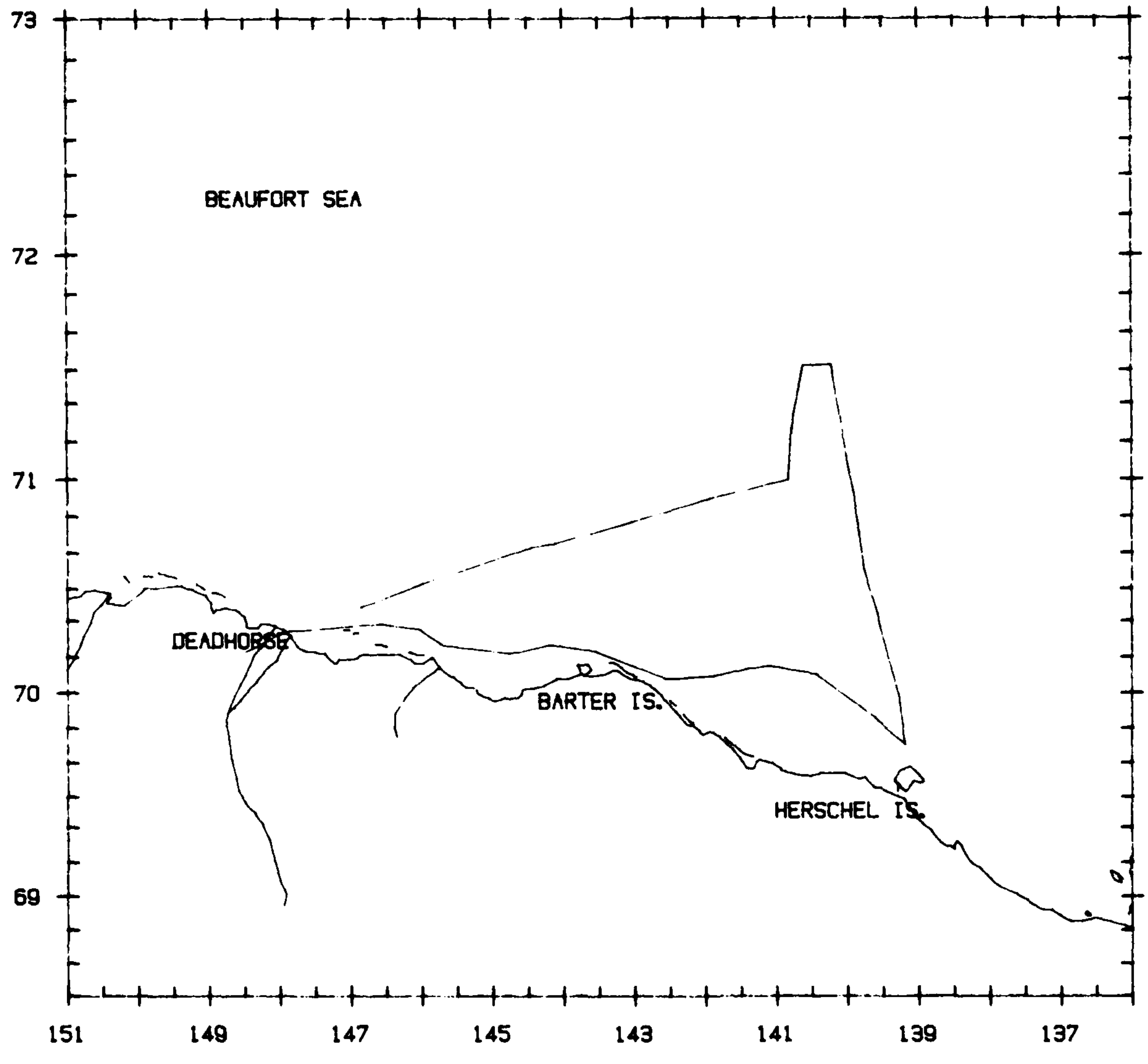
Flight 15: 6 August 1985

Flight was a search survey east to Herschel Island and a modified transect survey of parts of blocks 7 and 8 to identify ice conditions. Low-lying fog blanketed the Beaufort Sea west of Barter Island, but clear skies existed between Barter and Herschel Islands. Ice coverage in block 5 was 0 percent north to 70° N, and 30 to 95 percent broken floe north of there. West of Barter Island, 90 percent broken floe ice existed to within 5 km of shore. Sea state was Beaufort 00 in heavy ice areas and Beaufort 04 to 05 in open water areas. No marine mammals were seen.



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BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
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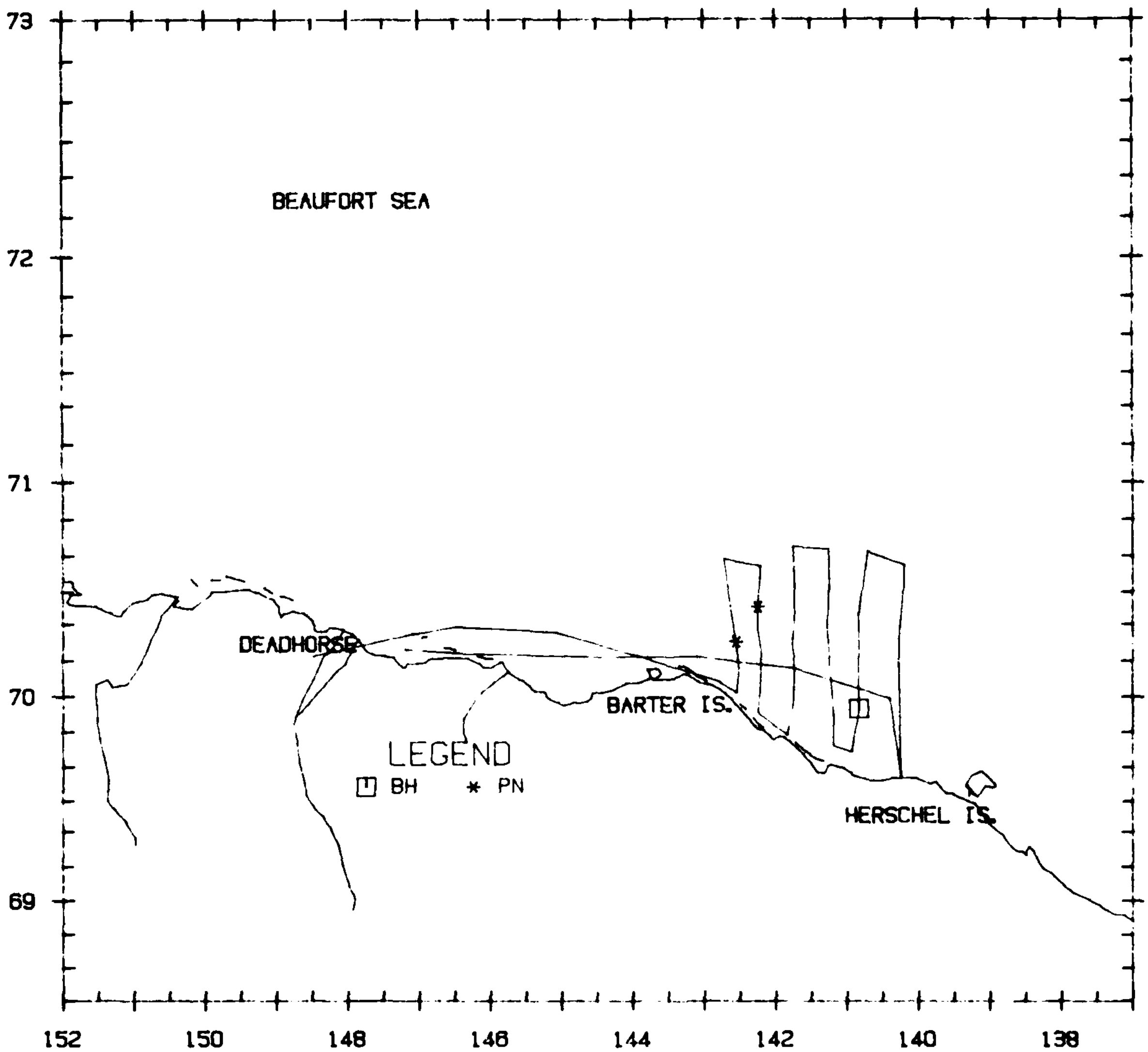
Flight 16: 7 August 1985

Flight was a transect survey of block 5 and the lower one-third of block 7. Weather was hazy, but with generally unlimited visibility. Ninety-five percent broken floe ice covered all of block 7 and the northern third of block 5. Sea state was Beaufort 00 in the heavy ice and Beaufort 02 to 03 in open water areas. One small bowhead was seen in block 5 swimming slowly. Unidentified pinnipeds were also seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	69°56.7'	140°50.1'	357	BO	SW	290	0	B3	37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BEAUFORT SEA
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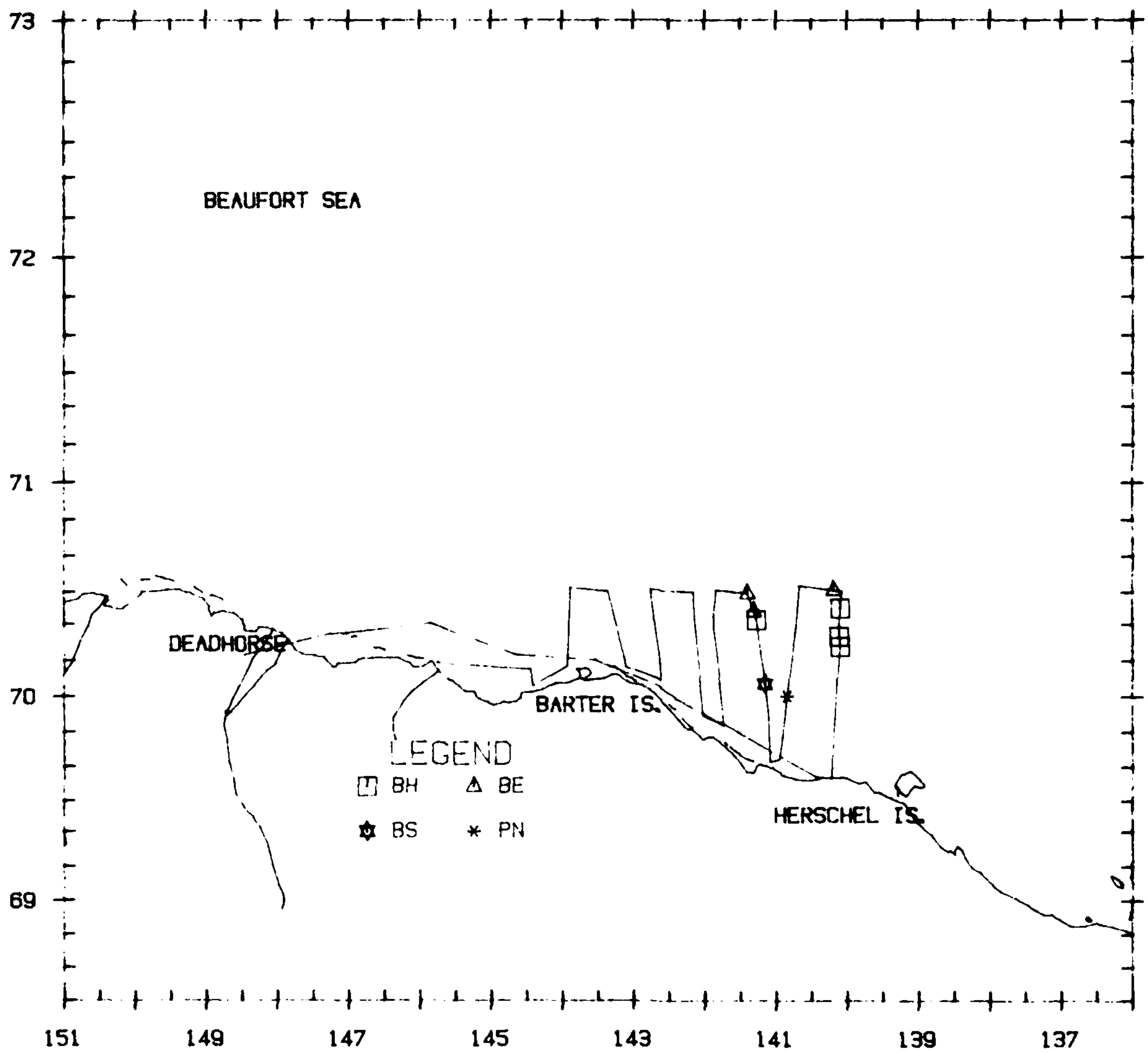
Flight 17: 8 August 1985

Flight was a transect survey of blocks 5 and 4. Aircraft mechanical problems forced us to abort the survey in block 4. Weather was overcast and hazy, with generally unlimited visibility. Block 5 was ice-free, except for 10 percent broken floe coverage near-shore. Block 4, except Camden Bay, was 10 to 85 percent covered with ice. Camden Bay was ice-free. Sea state ranged from Beaufort 00 to 03. Four bowheads, including one lone calf and one tail slapping, were seen in block 5. Belukhas, a bearded seal, and an unidentified pinniped were also seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/1	70°13.8'	140°06.1'	295	BO	RE	--	0	B1	62
1/0	70°16.7'	140°06.9'	2594	BO	SL	--	0	B1	73
1/0	70°24.3'	140°05.8'	3254	BW	SW	--	0	B1	115
1/0	70°21.1'	141°16.7'	398	BO	SW	60	0	B1	55



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BEAUFORT SEA
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HERSCHEL IS.
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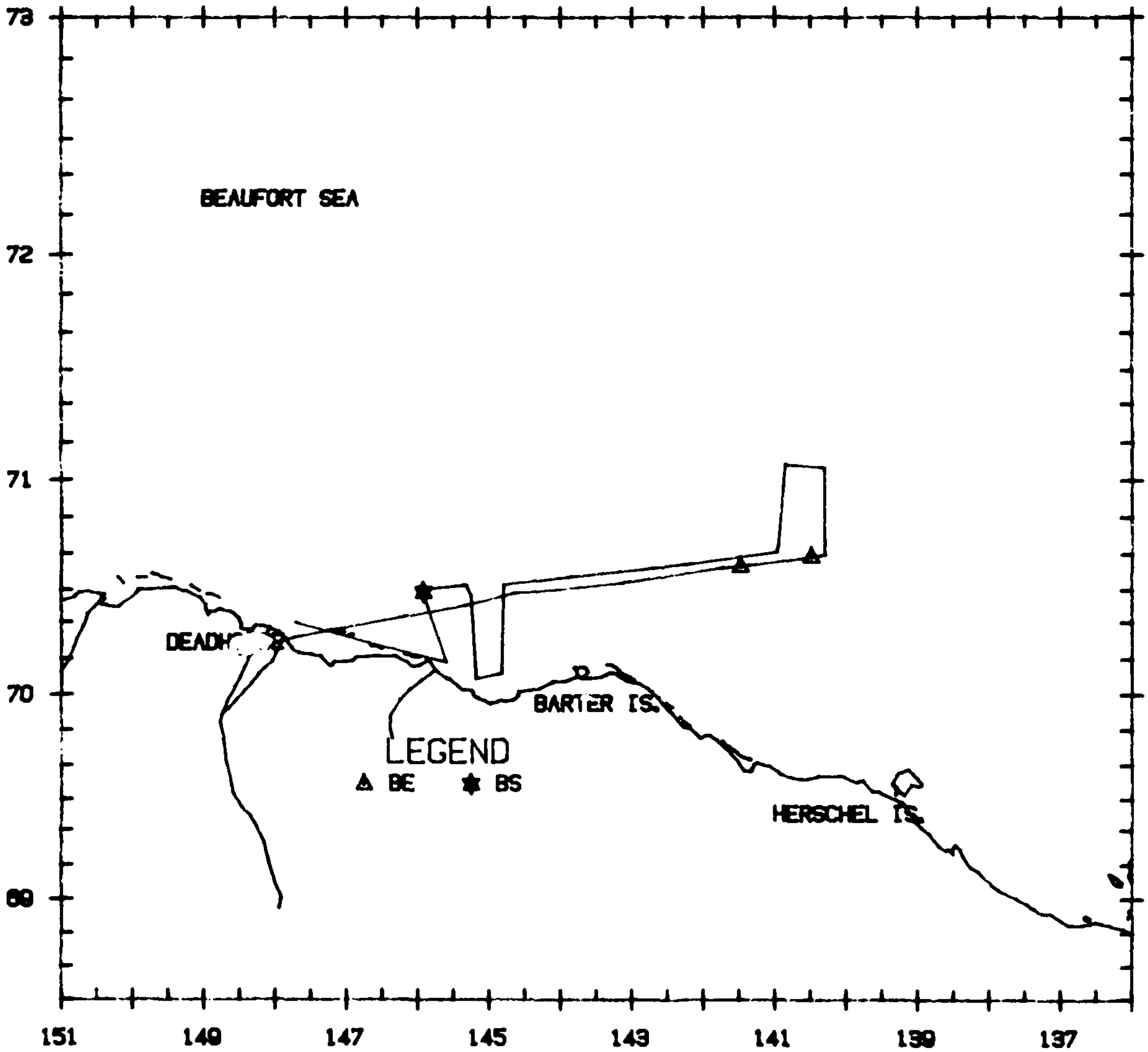
Flight 18: 9 August 1985

Flight was a transect survey of the western one-half of block 4 after low-lying fog prevented a planned survey of blocks 7 and 8. Weather in block 4 was overcast with unlimited visibility. Ice coverage was 10 to 40 percent in the southern two-thirds of the block and 90 to 95 percent in the northern one-third. Sea state was Beaufort 00 to 01. Belukhas and a bearded seal were seen.



BEAUFORT SEA
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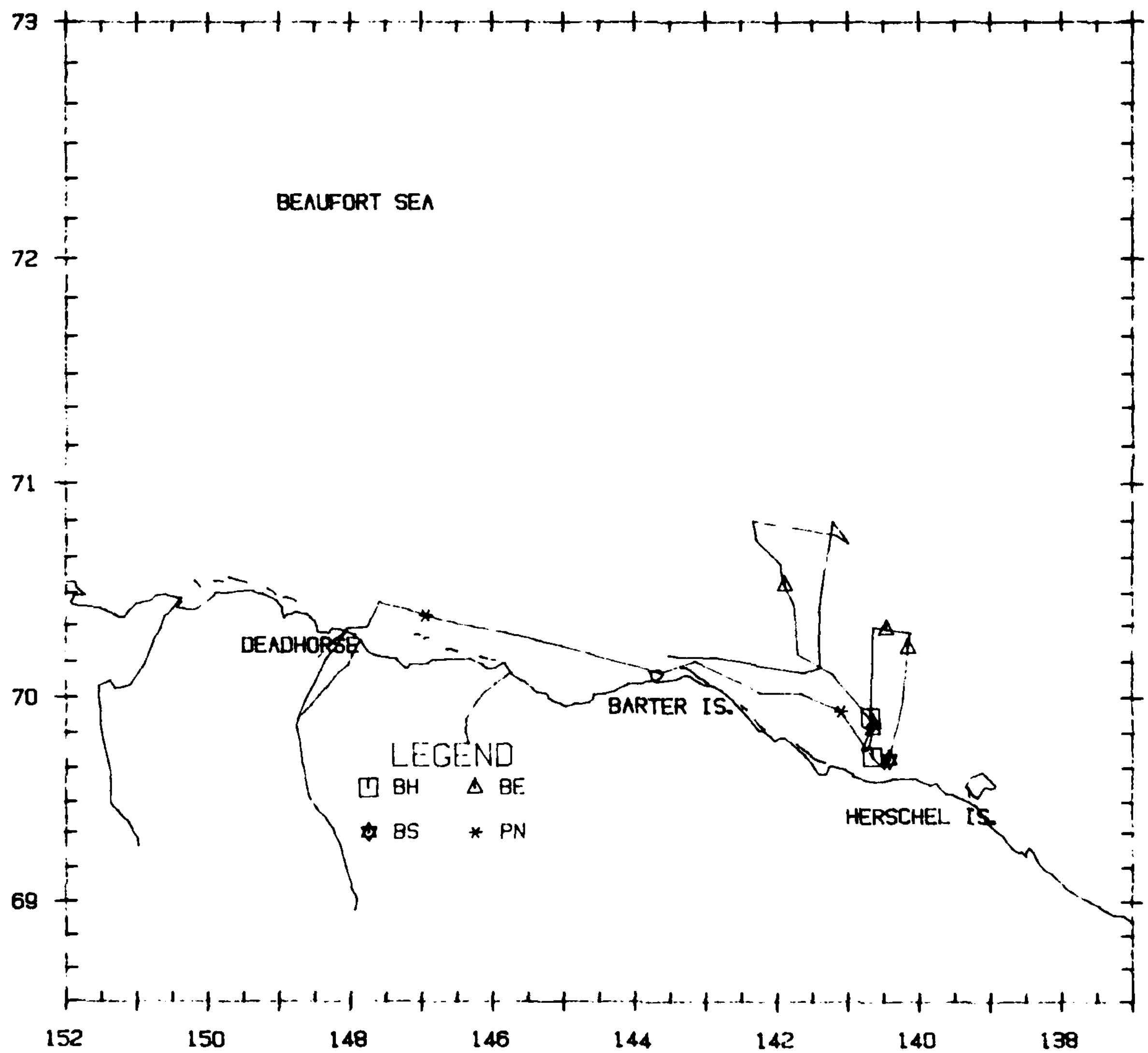
Flight 19: 11 August 1985

Flight was a modified transect survey of blocks 5 and 7. Dense, low-lying fog covered nearly all of the Alaskan Beaufort Sea. Visibility varied from unacceptable to 5 km. Ice coverage in block 5 was 0 percent and 95 percent in block 7. Sea state ranged from Beaufort 01 to 03. Three bowheads were seen in block 5. Belukhas, a bearded seal, and unidentified pinnipeds were also seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	69°43.5'	140°39.5'	286	BO	RE	110	2	B3	24
2/0	69°54.7'	140°41.2'	1215	BO	SW	--	0	B3	35



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BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
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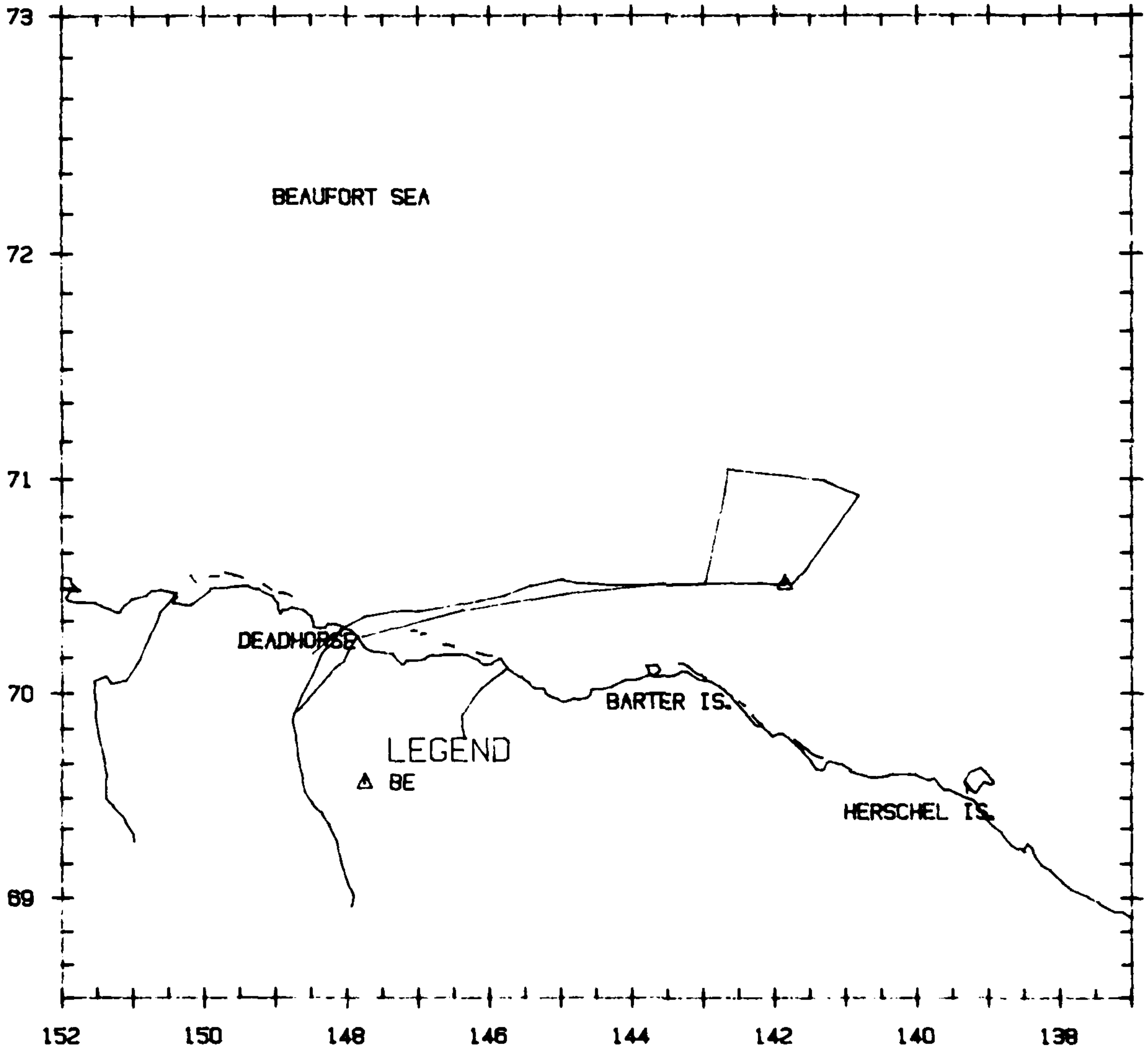
Flight 20: 12 August 1985

Flight was an aborted transect survey of block 7. Weather was dense, low-lying fog and visibility was unacceptable. Ice coverage in block 7 was 95 to 99 percent broken floe and sea state was Beaufort 00. Belukhas were seen.



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BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
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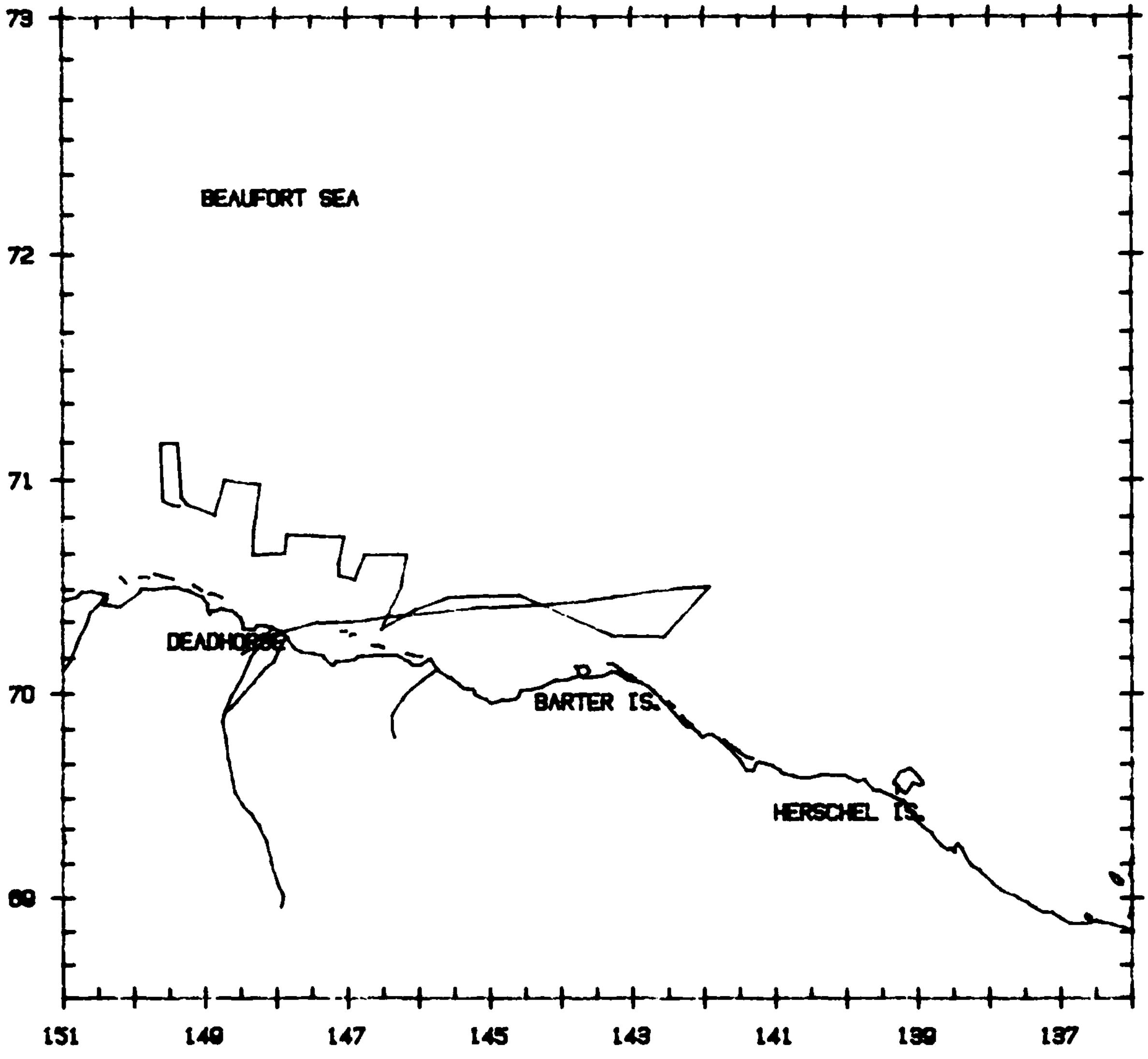
Flight 21: 14 August 1985

Flight was a transect survey of the northern one-half of block 1 after low-lying fog prevented surveys in the eastern Alaskan Beaufort Sea. Weather in block 1 was clear with unlimited visibility in the northern half and heavy fog in the southern half. Ice coverage was 80 to 95 percent broken floe and sea state was Beaufort 00. No marine mammals were seen.



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BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
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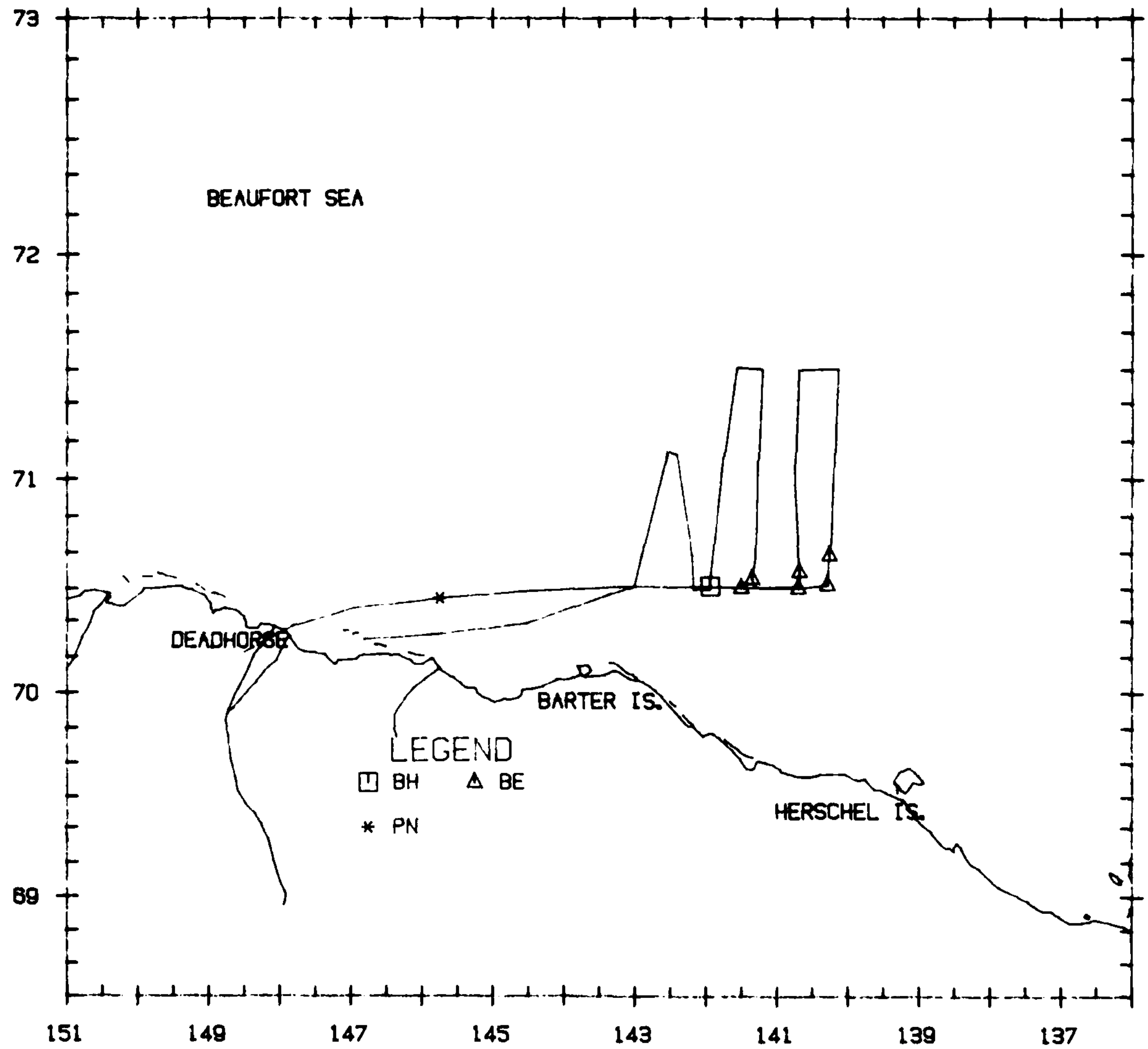
Flight 22: 15 August 1985

Flight was a transect survey of block 7 and the southern one-half of block 8. Weather was mostly overcast with some patchy fog and visibility was generally unlimited. Ice coverage was 0 to 10 percent along the southernmost edge of block 7 and 95 to 99 percent in the rest of block 7 and all of block 8. Sea state was Beaufort 00 to 02. One bowhead was seen tail slapping in block 7. Belukhas were also seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°30.9'	141°55.7'	--	BO	SL	--	0	B1	146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BEAUFORT SEA
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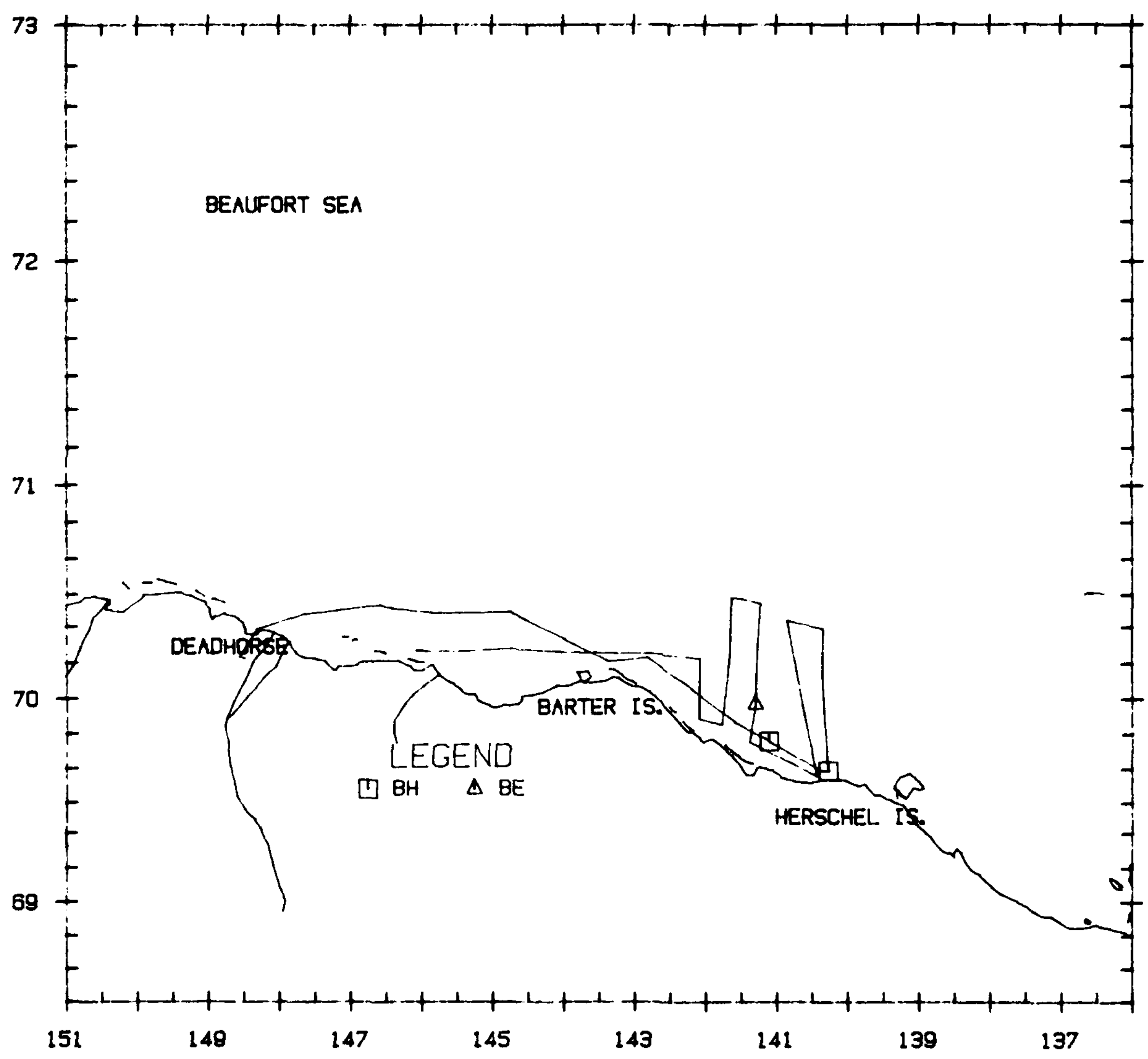
Flight 23: 17 August 1985

Flight was a transect survey of the eastern two-thirds of block 5. Weather was overcast with unlimited visibility in this area. Heavy fog covered the rest of the Alaskan Beaufort Sea. Ice coverage was 0 to 10 percent broken floe, except along the northernmost edge of block 5. Sea state was Beaufort 01 to 02. Two bowheads were seen swimming. Belukhas were also seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	69°48.0'	141°06.1'	--	BO	SW	240	5	B2	22
1/0	69°39.5'	140°15.5'	--	BO	SW	--	2	B2	16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BEAUFORT SEA
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HERSCHEL IS.
LEGEND
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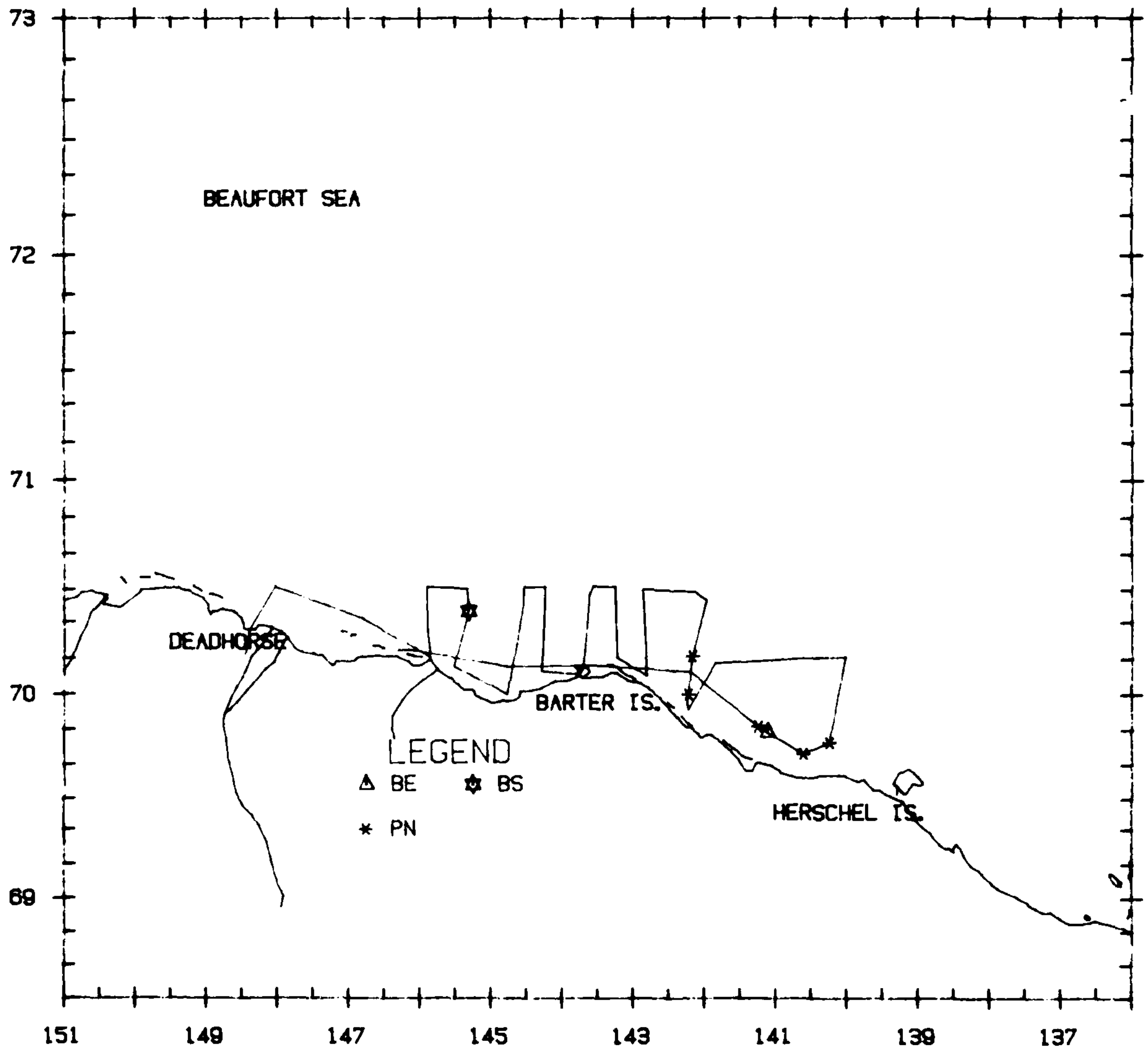
Flight 24: 18 August 1985

Flight was a transect survey of block 4 and the westernmost one-third of block 5 and a search survey to 140° W. Weather was clear with unlimited visibility. Ice coverage was 10 to 40 percent in the southern two-thirds of block 4 and all of block 5 and 95 to 99 percent in the northern third of block 4. Sea state was Beaufort 00 to 01. Belukhas, bearded seals and unidentified pinnipeds were seen.



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BEAUFORT SEA
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BARTER IS.
HERSCHEL IS.
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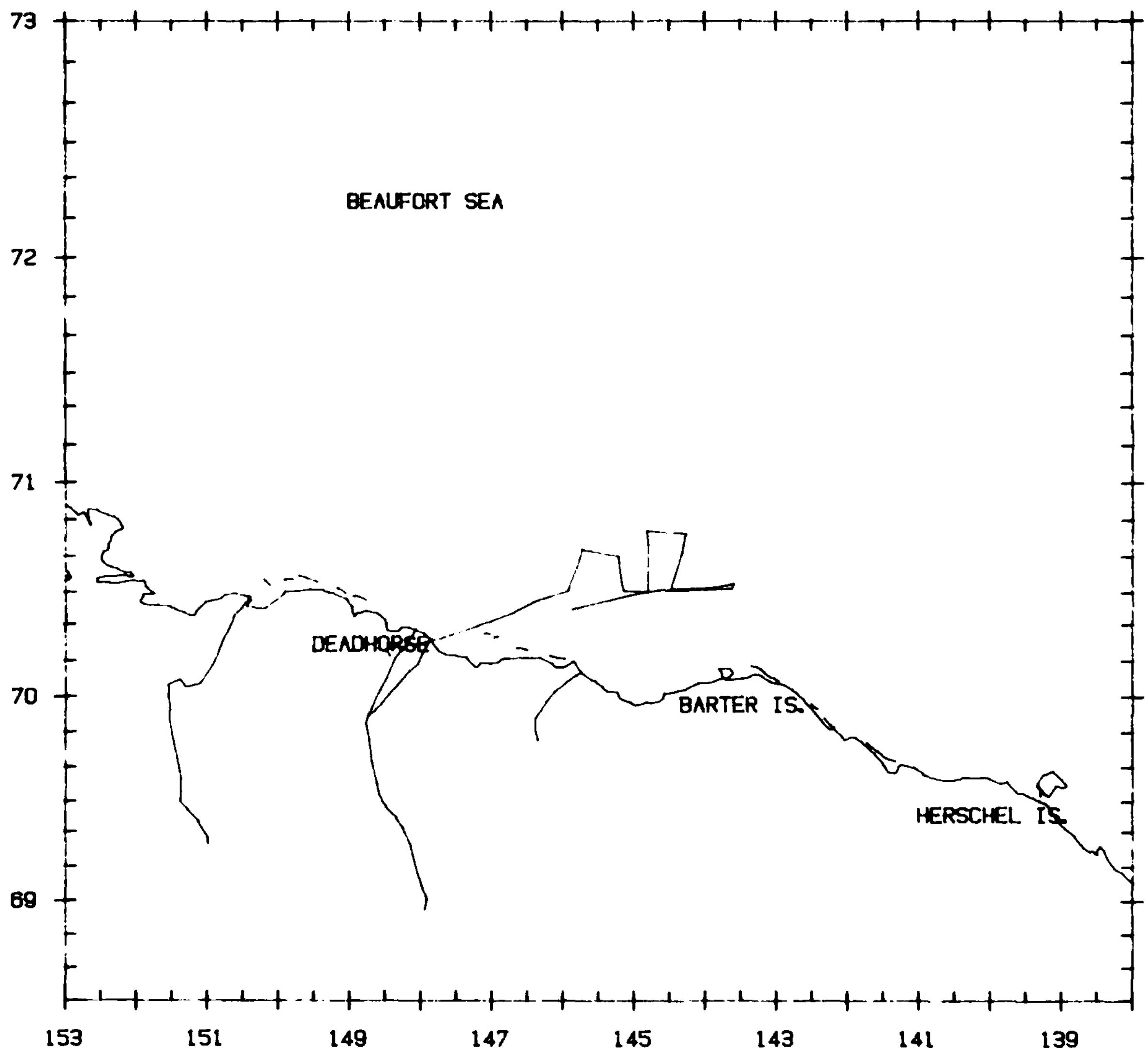
Flight 25: 19 August 1985

Flight was a modified transect survey of block 6. Heavy fog blanketed the rest of the Alaskan Beaufort Sea. Visibility was variable from 10 km to unacceptable. Ice coverage was 95 to 99 percent broken floe and sea state was Beaufort 00. No marine mammals were seen.



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BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
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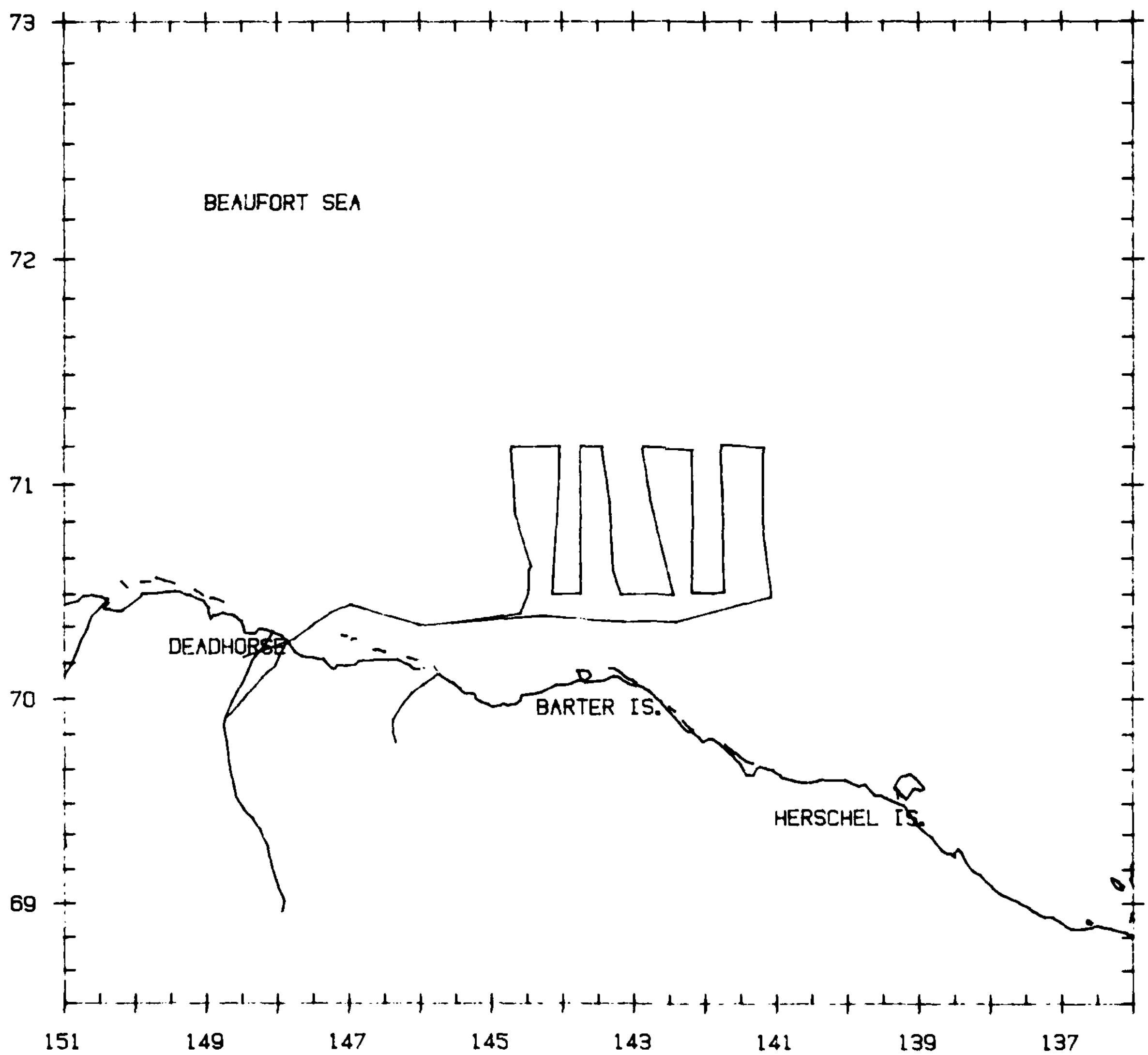
Flight 26: 21 August 1985

Flight was a transect survey of the eastern two-thirds of block 6 and the western two-thirds of block 7. Weather was clear with unlimited visibility. Ice coverage was 95 to 99 percent in all areas of both blocks except for the southernmost edge, which was ice-free. Sea state was Beaufort 00 in the ice and Beaufort 04 in open water areas.



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BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
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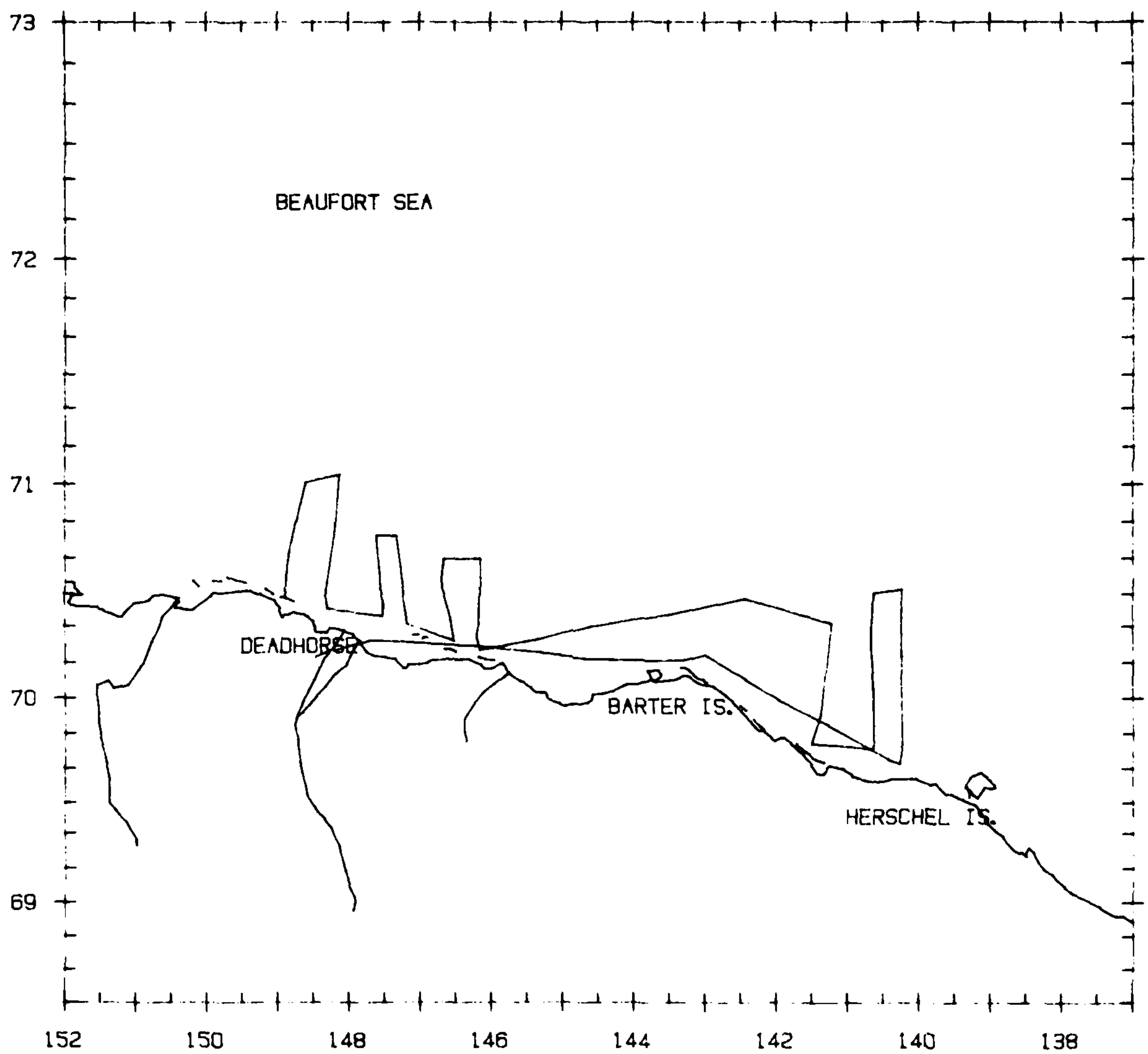
Flight 27: 24 August 1985

Flight was a transect survey of the eastern one-half of block 5 and the eastern three-quarters of block 1. Weather was clear with unlimited visibility. Ice coverage was 0 to 10 percent in block 5 and 0 to 99 percent in block 1. Sea state was Beaufort 05 in block 5 and varied from Beaufort 00 to 02 in block 1. No marine mammals were seen.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BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
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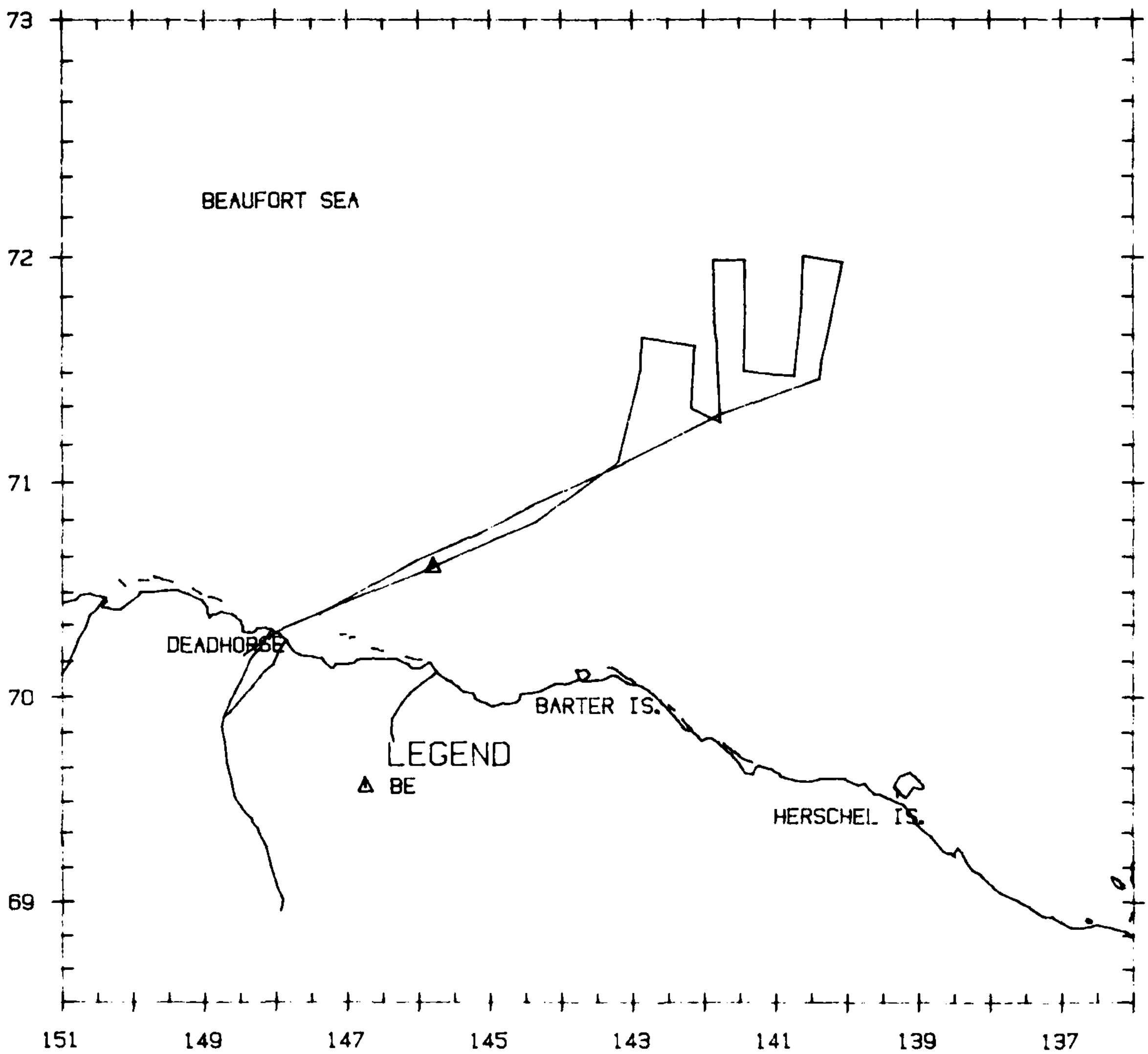
Flight 28: 25 August 1985

Flight was a modified transect survey of block 8. Low-lying fog forced some transect lines to be truncated, but the majority of the block was clear with unlimited visibility. Ninety-nine percent broken floe ice covered the entire block and the sea state was Beaufort 00. One belukha was seen.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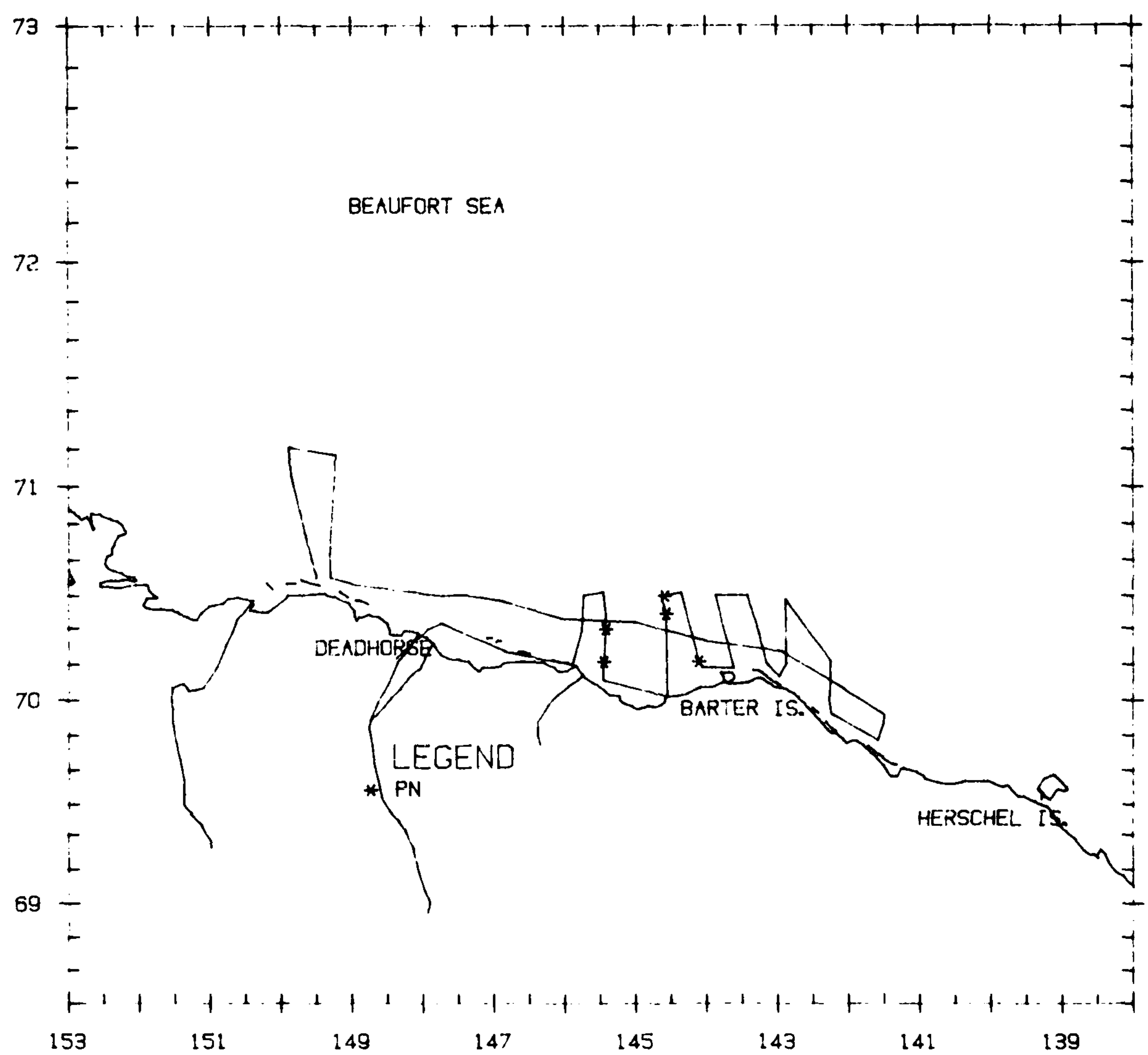
Flight 29: 27 August 1985

Flight was a transect survey of block 4 and parts of blocks 5 and 1. Weather was generally clear with unlimited visibility except in the northern portion of block 5 where low-lying fog existed. Ice coverage in blocks 4 and 5 was 0 to 10 percent broken floe with sea state ranging from Beaufort 01 to 03. Ice coverage in block 1 varied from 0 to 95 percent, with sea state ranging from Beaufort 00 to 01. Unidentified pinnipeds were seen.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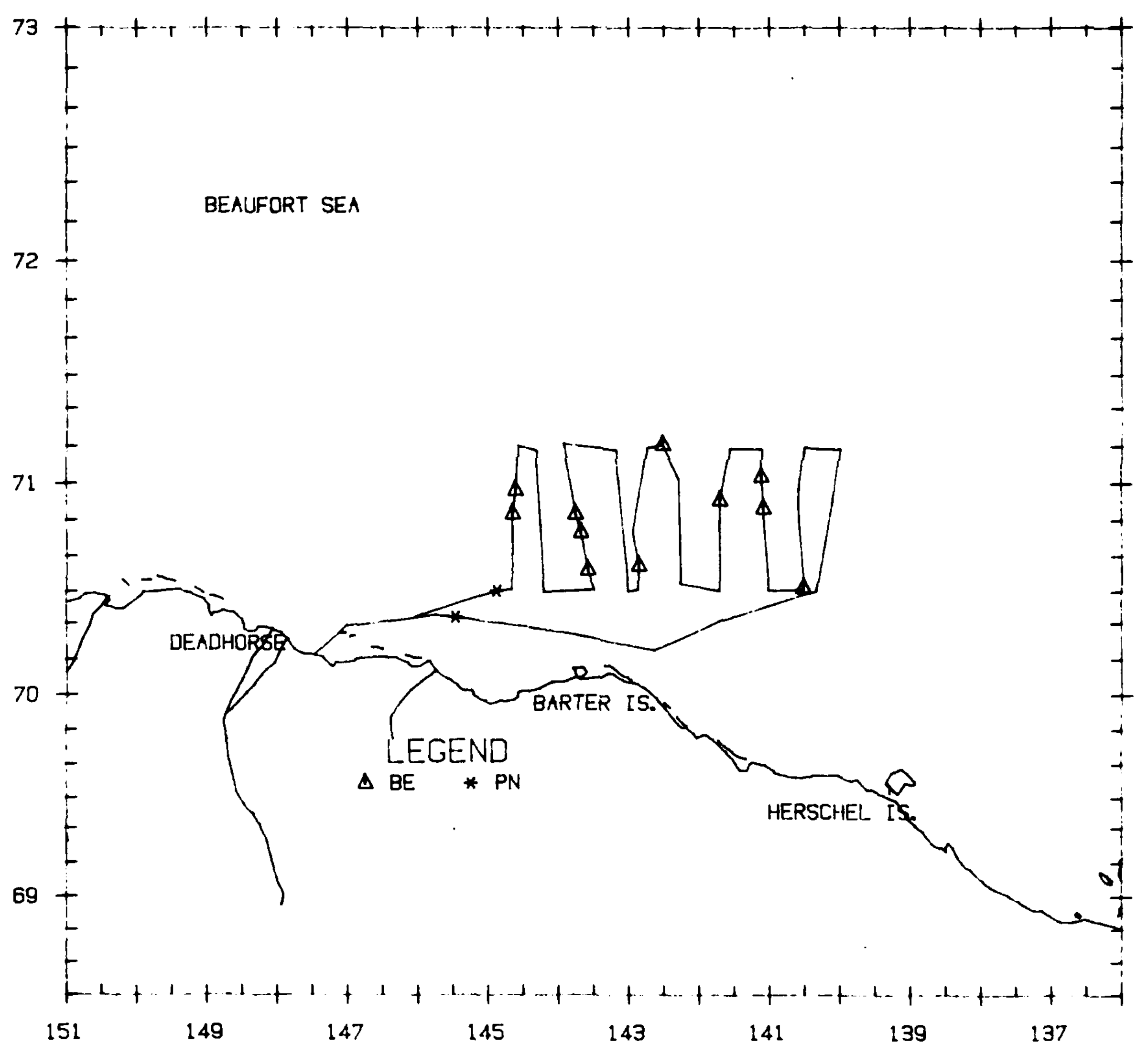
Flight 30: 28 August 1985

Flight was a transect survey of blocks 7 and 6. Weather was clear with unlimited visibility. Ice coverage was 85 to 99 percent in the northern half of each block and 0 to 30 percent in the southern half. Sea state was Beaufort 00 in the heavy ice and Beaufort 01 in open water. Belukhas and unidentified pinnipeds were seen.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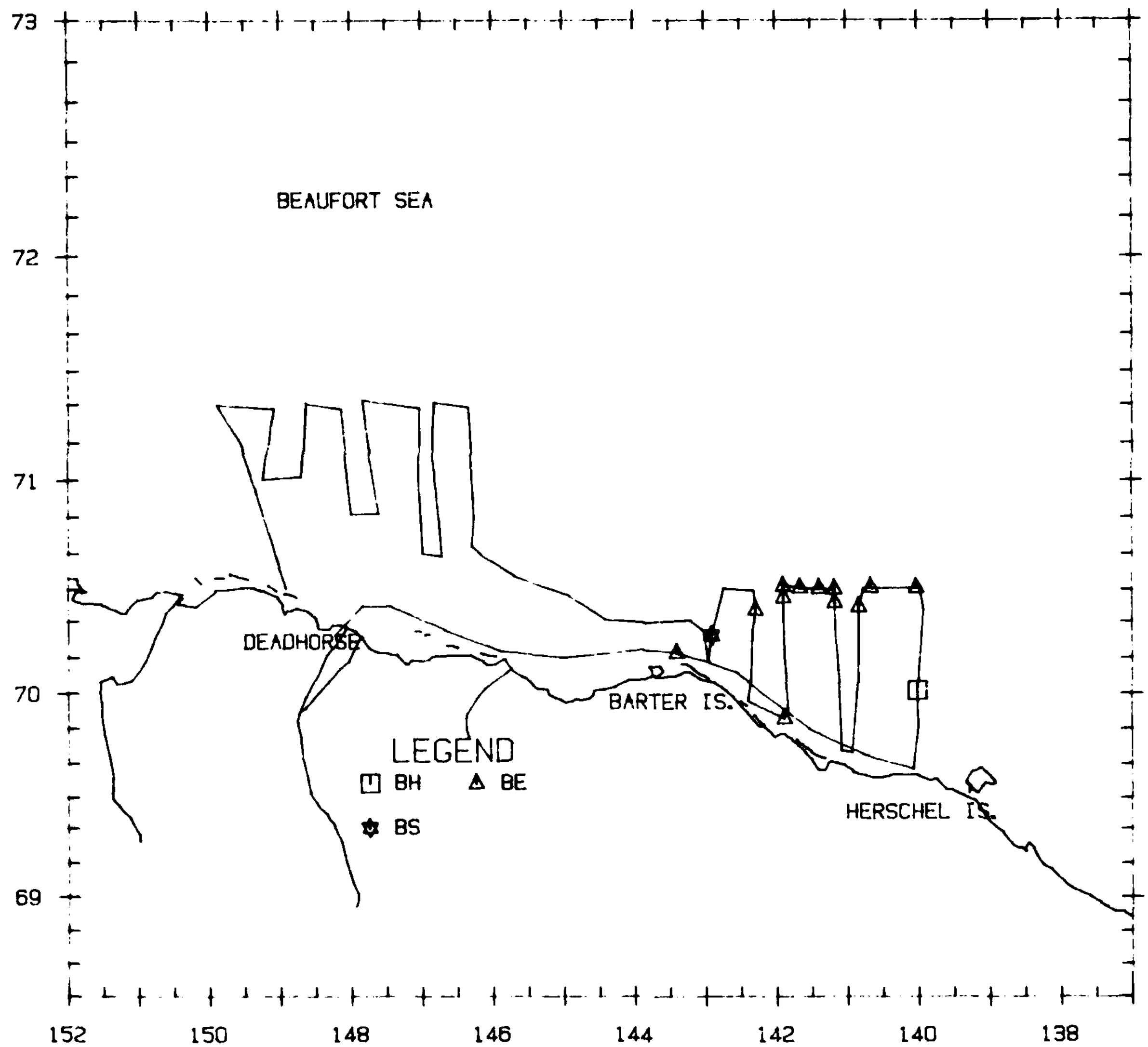
Flight 31: 29 August 1985

Flight was a transect survey of blocks 5 and 2. Weather was generally clear with some patchy fog and visibility varied from 3 km to unlimited. There was no ice in block 5, with a sea state of Beaufort 01. Ice coverage in block 2 was 50 to 99 percent, with a sea state of Beaufort 00 to 01. One bowhead was seen swimming. Belukhas and a bearded seal were also seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°01.0'	140°00.8'	527	BO	SW	45	0	B2	59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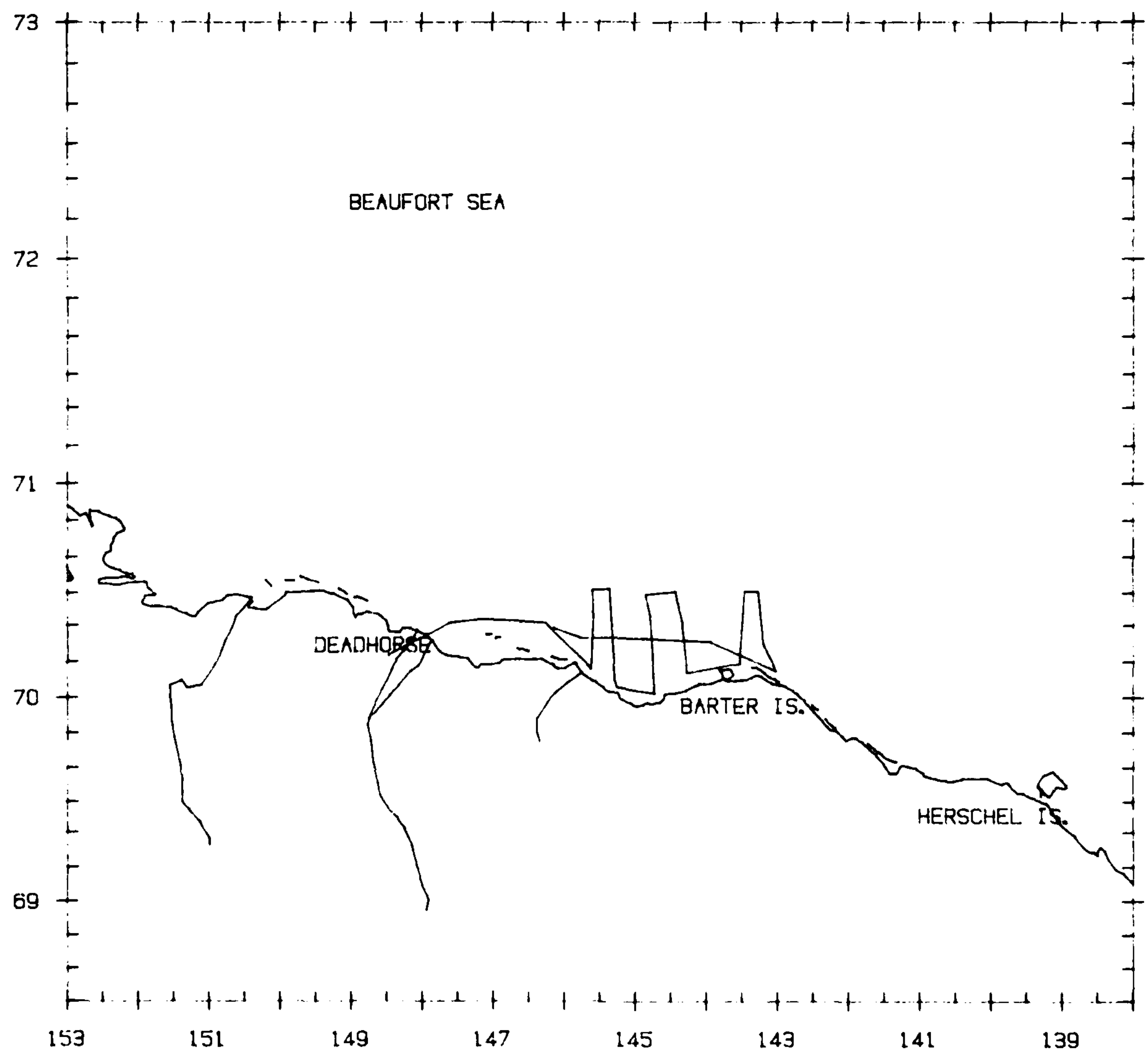
Flight 32: 30 August 1985

Flight was a transect survey of block 4. Weather was overcast with unlimited visibility. Ice coverage was 0 to 5 percent and sea state was Beaufort 01. No marine mammals were seen.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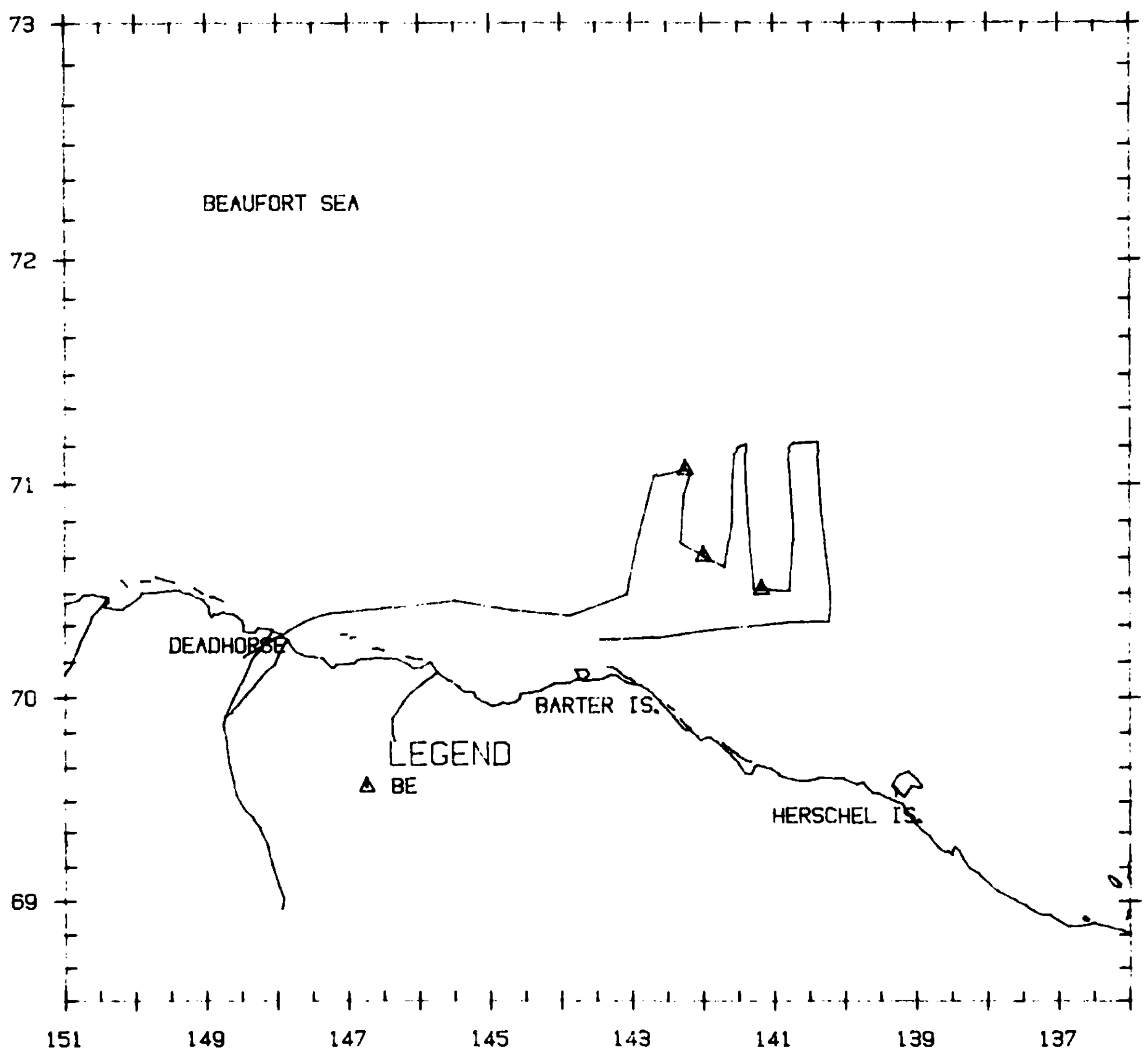
Flight 33: 1 September 1985

Flight was a transect survey of block 7. Heavy fog surrounding the area forced some transect legs to be truncated, as visibility varied from 10 km to unacceptable. Ice coverage was 0 percent in all but the northernmost areas, where 20 to 50 percent broken floe ice persisted. Sea state was Beaufort 05 to 06. Belukhas were the only marine mammals seen.



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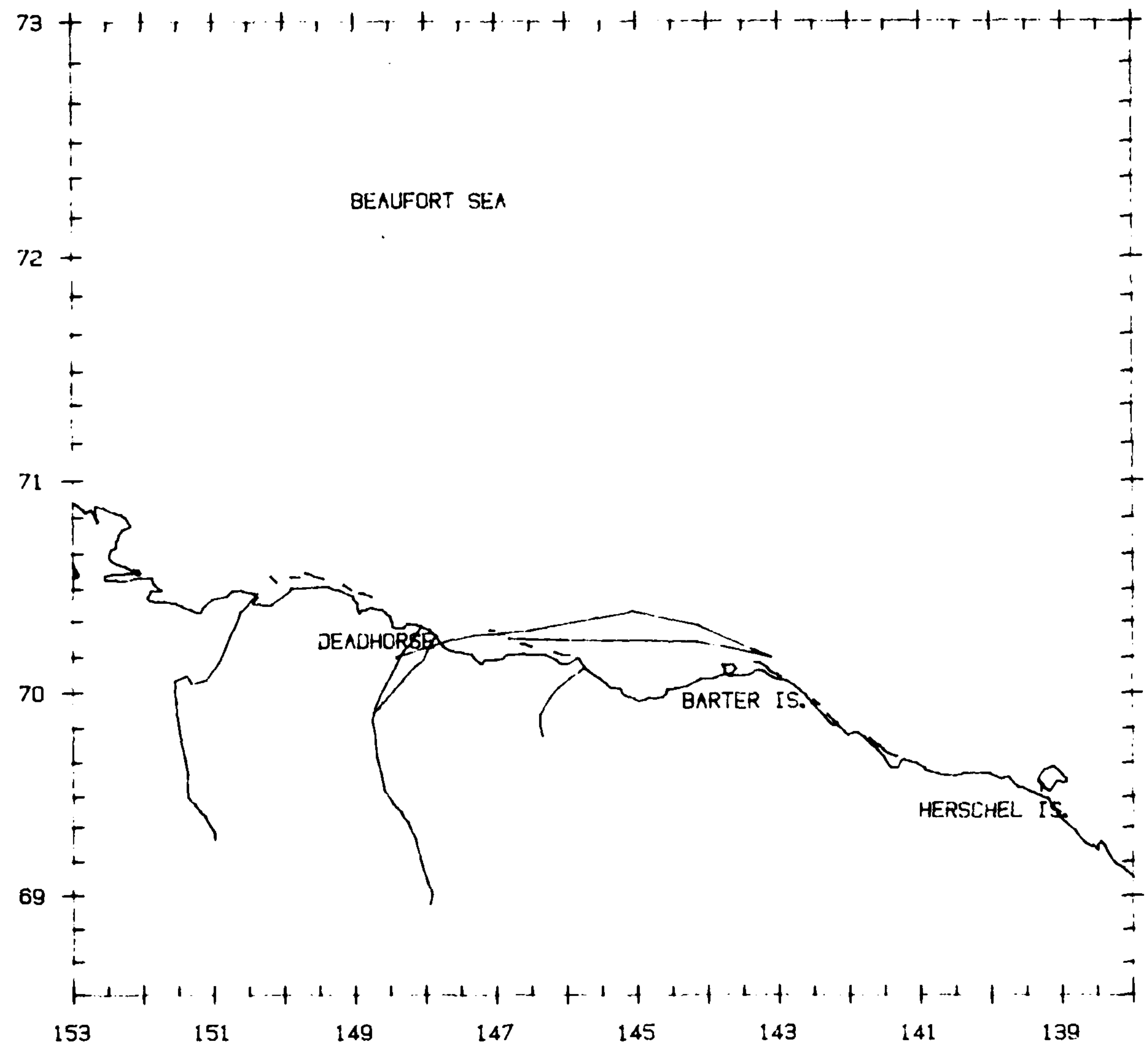
Flight 34: 4 September 1985

Flight was a search survey east to Barter Island. Heavy, low-lying fog covered the Alaskan Beaufort Sea and visibility was unacceptable. Ice coverage along the barrier islands was about 30 percent and sea state was Beaufort 03. No marine mammals were seen.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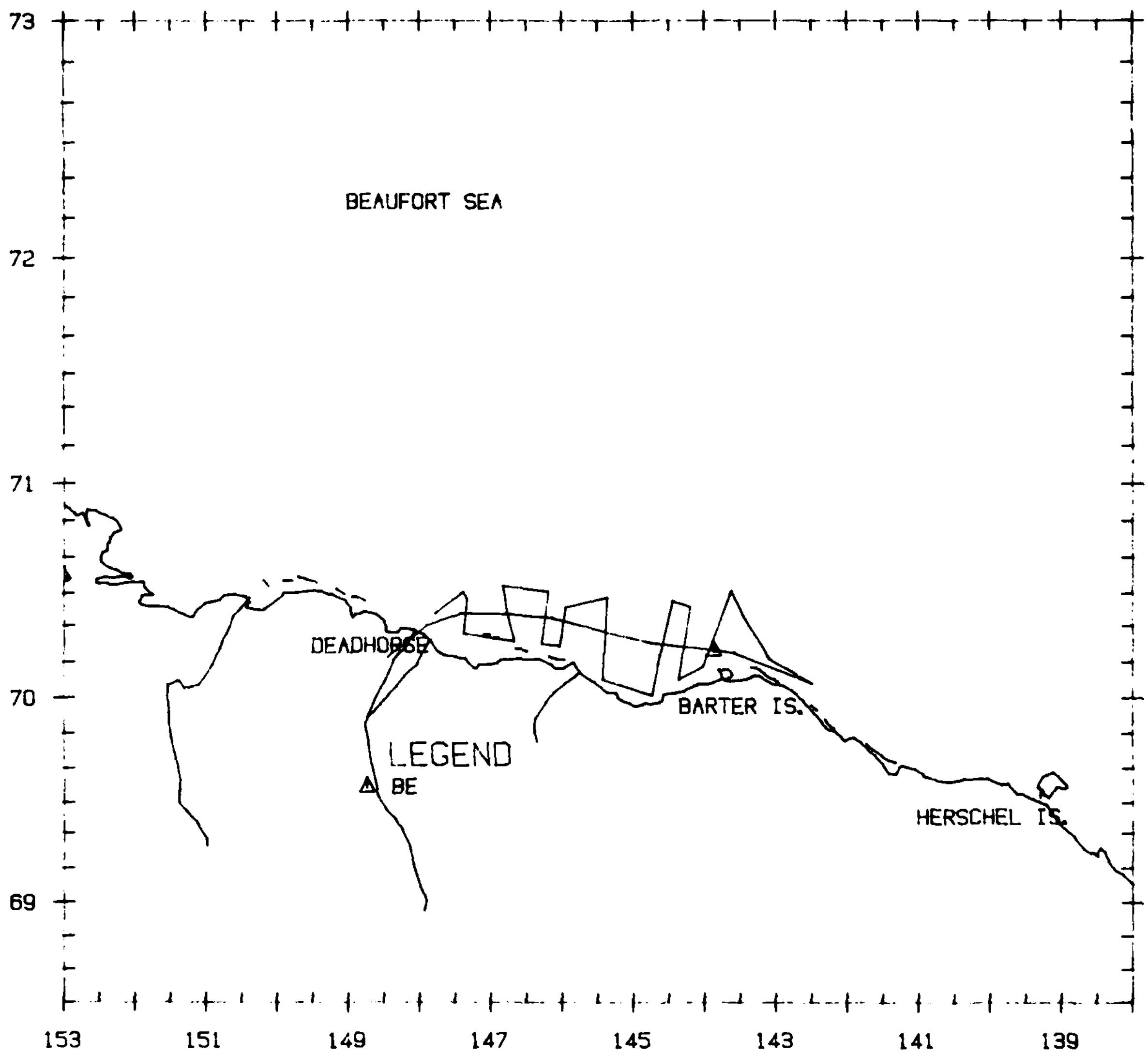
Flight 35: 5 September 1985

Flight was a transect survey of block 4 and the southeast corner of block 1. Heavy fog forced transect legs to be truncated and the survey of block 1 to be aborted. Visibility was variable from 10 km to unacceptable. Ice coverage was 0 to 5 percent in block 4 and 0 to 40 percent in block 1. Sea state was Beaufort 02 to 03. One belukha was seen.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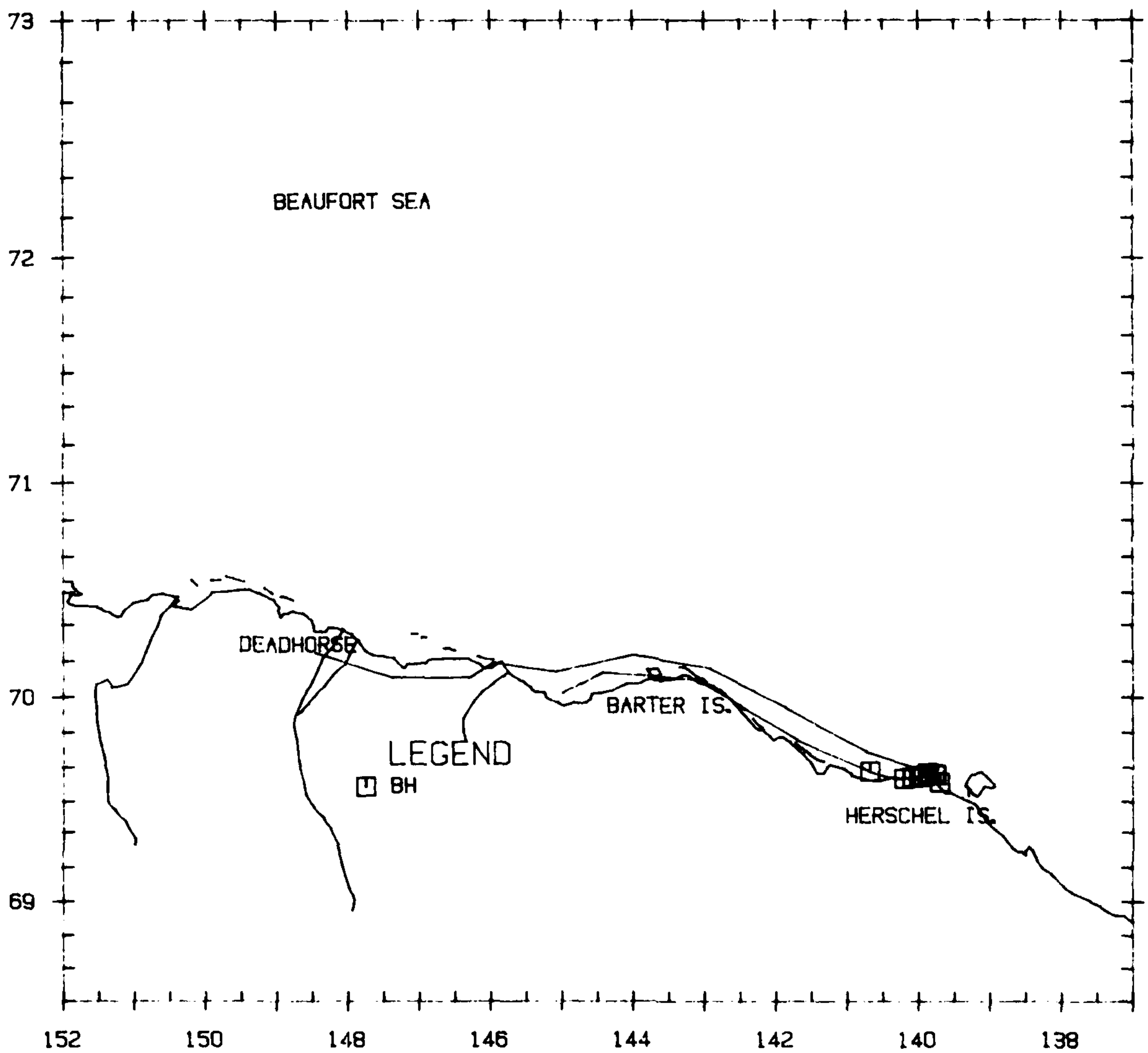
Flight 36: 9 September 1985

Flight was a search survey east to Herschel Island. Heavy, low-lying fog over the entire Alaskan Beaufort Sea prevented any transect surveys. One open area existed between 141° W and 139° W, in which sea state was Beaufort 03 and there was no ice. Twenty-five bowheads were seen there, milling and possibly feeding. No other marine mammals were seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
2/0	69°35.5'	139°41.8'	--	BO	RE	--	0	B2	15
3/0	69°37.8'	139°45.9'	--	BO	FE	--	0	B2	15
1/0	69°38.2'	139°51.9'	--	BO	FE	--	0	B2	15
1/0	69°37.6'	139°45.0'	--	BW	FE	--	0	B2	15
2/0	69°37.4'	139°55.8'	--	BW	FE	--	0	B2	15
5/0	69°37.1'	139°59.2'	--	BO	FE	--	0	B2	15
4/0	69°37.0'	140°05.0'	--	BO	FE	--	0	B2	16
5/0	69°36.6'	140°11.9'	--	BO	FE	--	0	B2	16
2/0	69°38.7'	140°40.7'	--	BO	FE	--	4	B3	7



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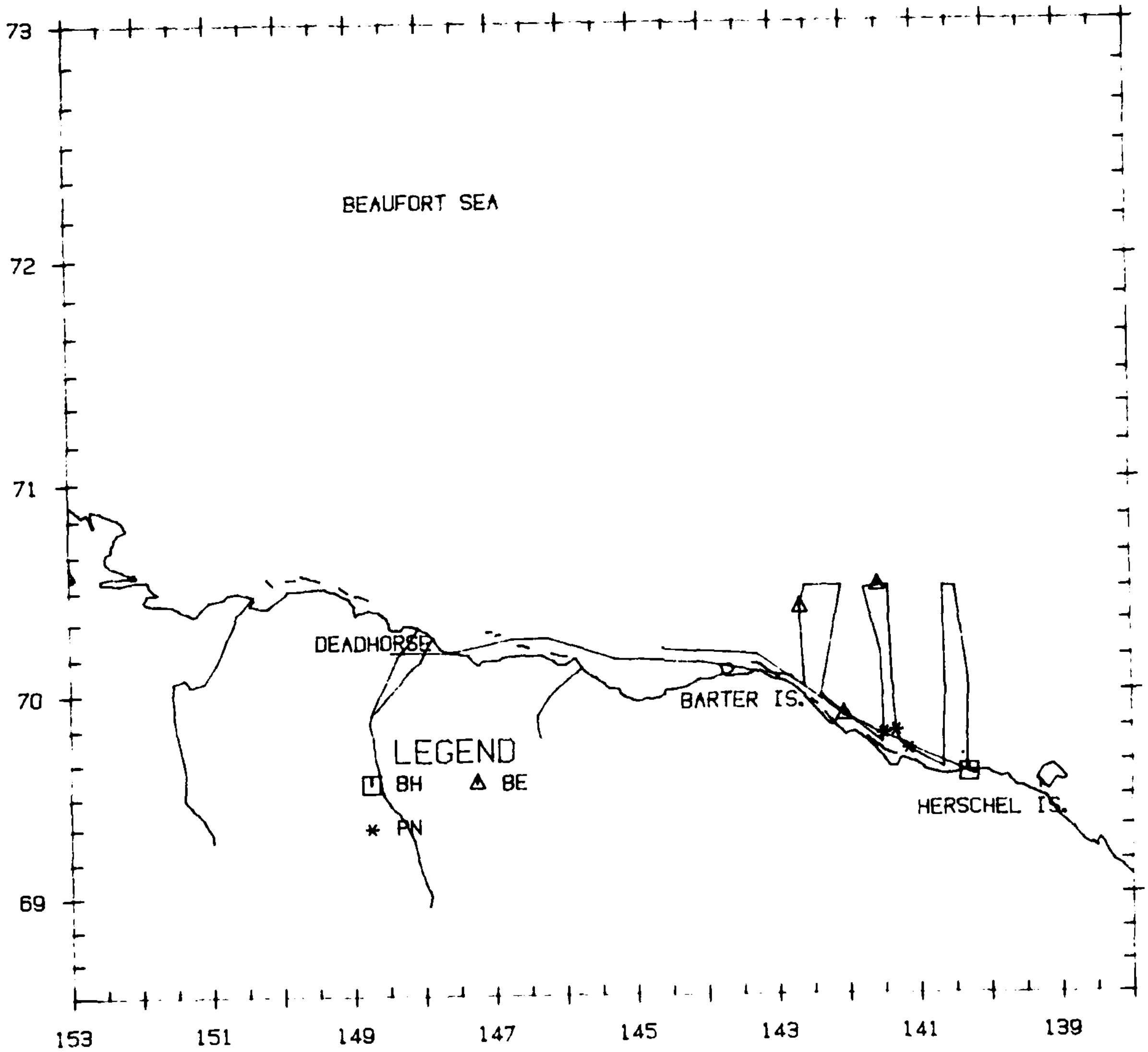
Flight 37: 11 September 1985

Flight was a transect survey of block 5, with a search survey through block 4. Intermittent heavy fog resulted in visibility that ranged from 10 km to unacceptable. Ice coverage was 0 to 5 percent, and sea state was Beaufort 01 to 02. Three bowheads were seen near-shore east of block 5. Belukhas and unidentified pinnipeds were also seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
3/0	69°36.4'	140°17.8'	--	BO	MI	60	0	B2	16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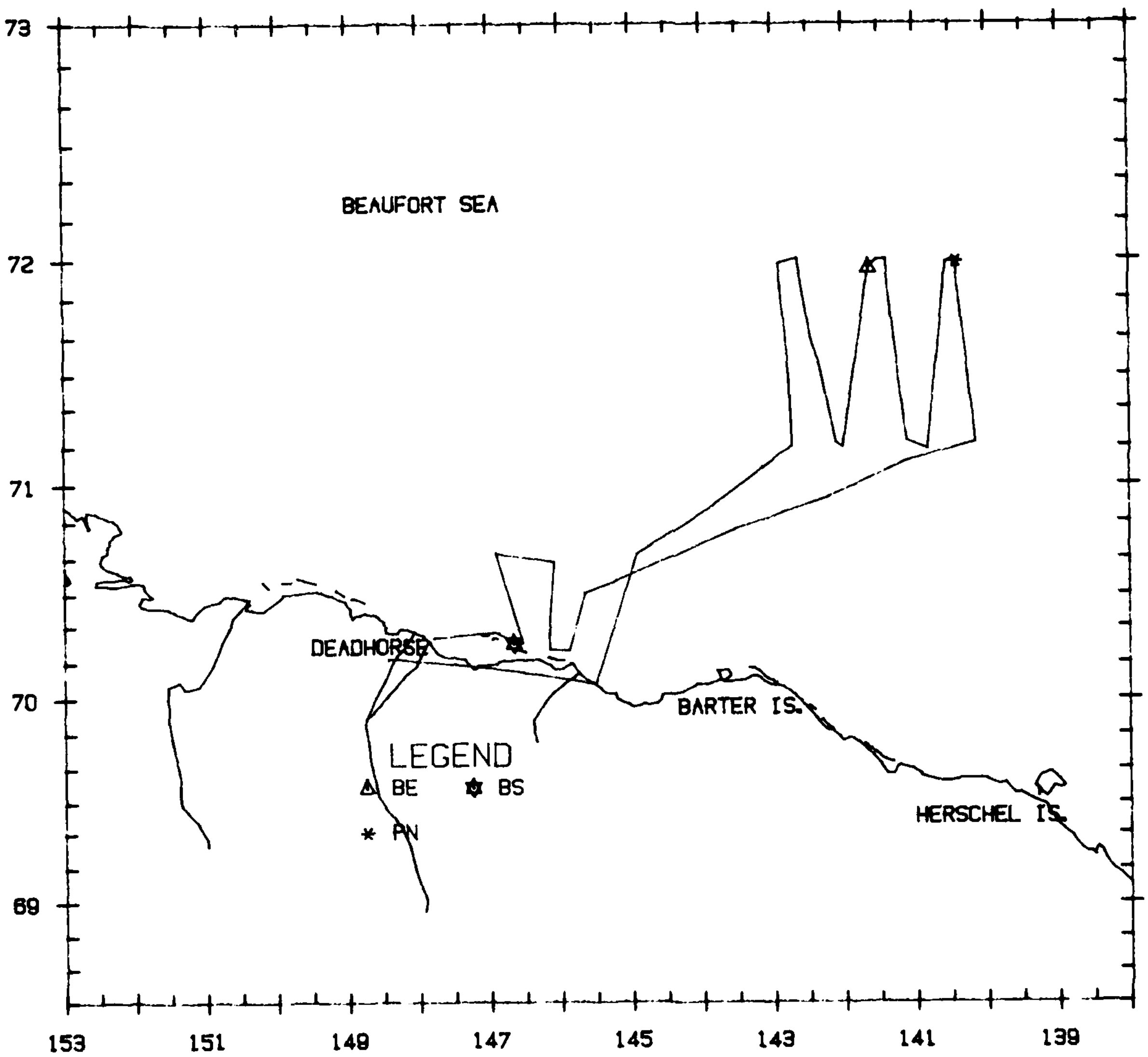
Flight 38: 12 September 1985

Flight was a transect survey of block 8 and one and two survey lines in blocks 4 and 1 respectively. Weather was partly cloudy with an area of low overcast with patchy fog in the northeastern corner of block 8. Visibility ranged from 0.5 km to unlimited. All areas had less than 1 percent ice coverage except the northern half of block 8 where ice coverage ranged from 40 to 99 percent. Sea state was Beaufort 00 to 02. A belukha, bearded seals and unidentified pinnipeds were seen.



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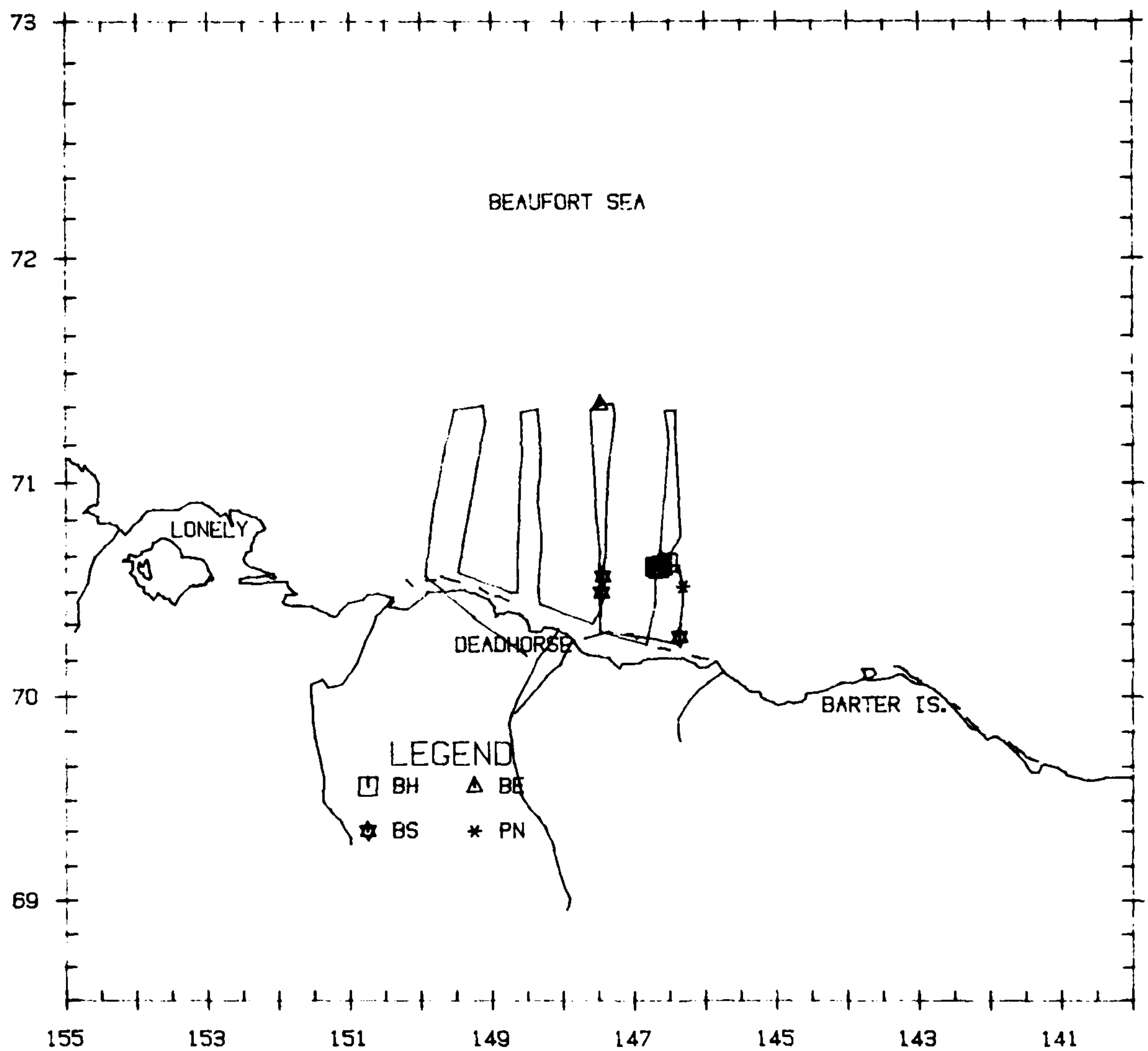
Flight 39: 13 September 1985

Flight was a transect survey of blocks 1 and 2. Weather was overcast with occasional rain showers. Visibility ranged from 3 km to unlimited, and sea state from Beaufort 01 to 03. Ice coverage ranged from 0 to 90 percent in block 1, and from 60 to 95 percent in block 2. Six bowheads, a belukha, bearded seals and an unidentified pinniped were seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
3/0	70°37.3'	146°41.3'	2353	BO	MI	--	0	B2	31
2/0	70°36.8'	146°38.8'	--	BO	SW	--	0	B2	29
1/0	70°38.3'	146°31.2'	--	BW	SW	360	0	B2	29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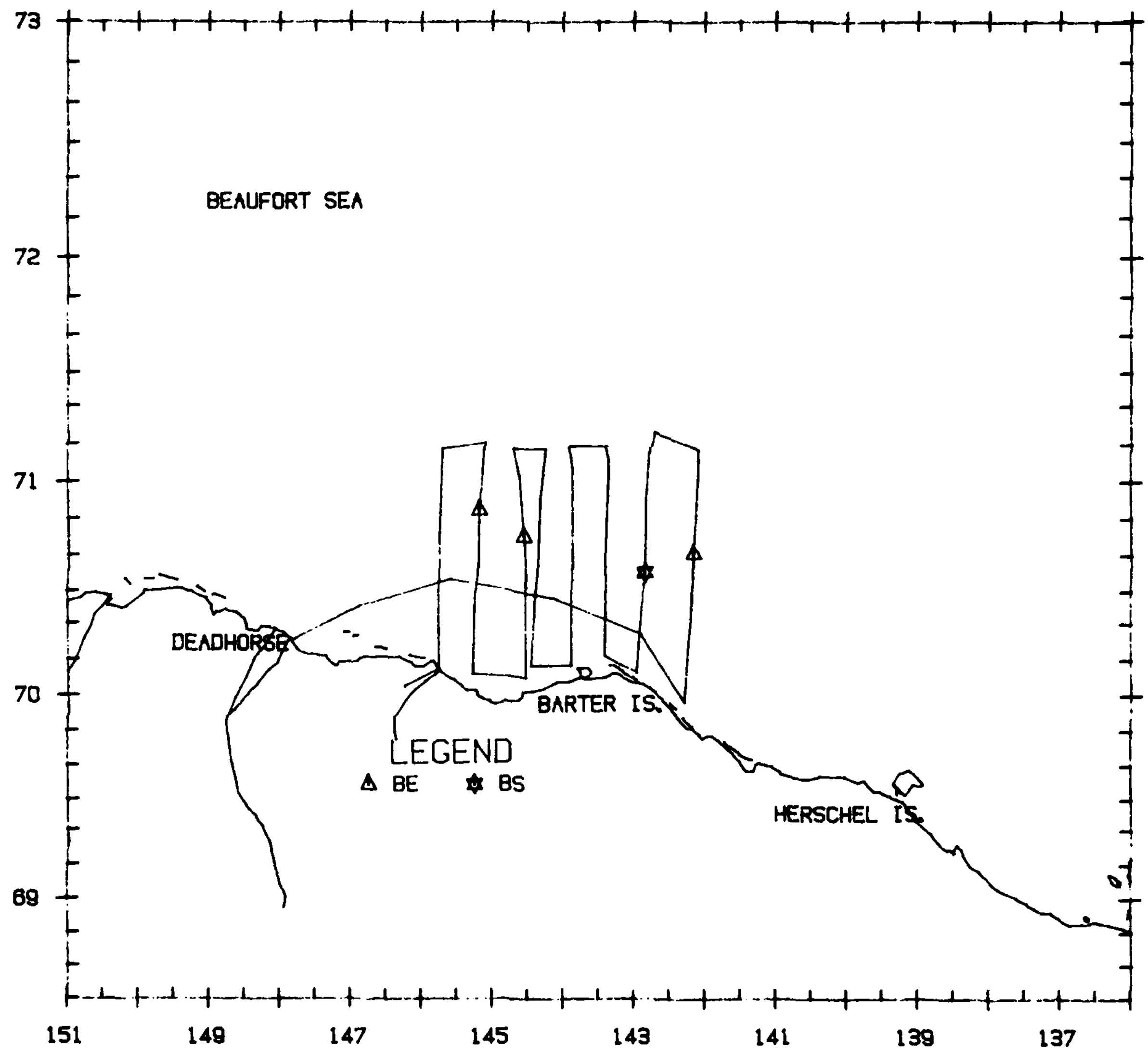
Flight 40: 18 September 1985

Flight was a transect survey of blocks 4 and 6 and the western one-third of blocks 5 and 7. Weather varied from partly cloudy near-shore, to low overcast at the northern extreme of blocks 6 and 7. Visibility ranged from 5 km to unlimited. Ice coverage was 2 to 90 percent in blocks 4 and 5, and 50 to 95 percent in blocks 6 and 7. Sea state was Beaufort 00 to 01. Belukha whales and a bearded seal were seen.



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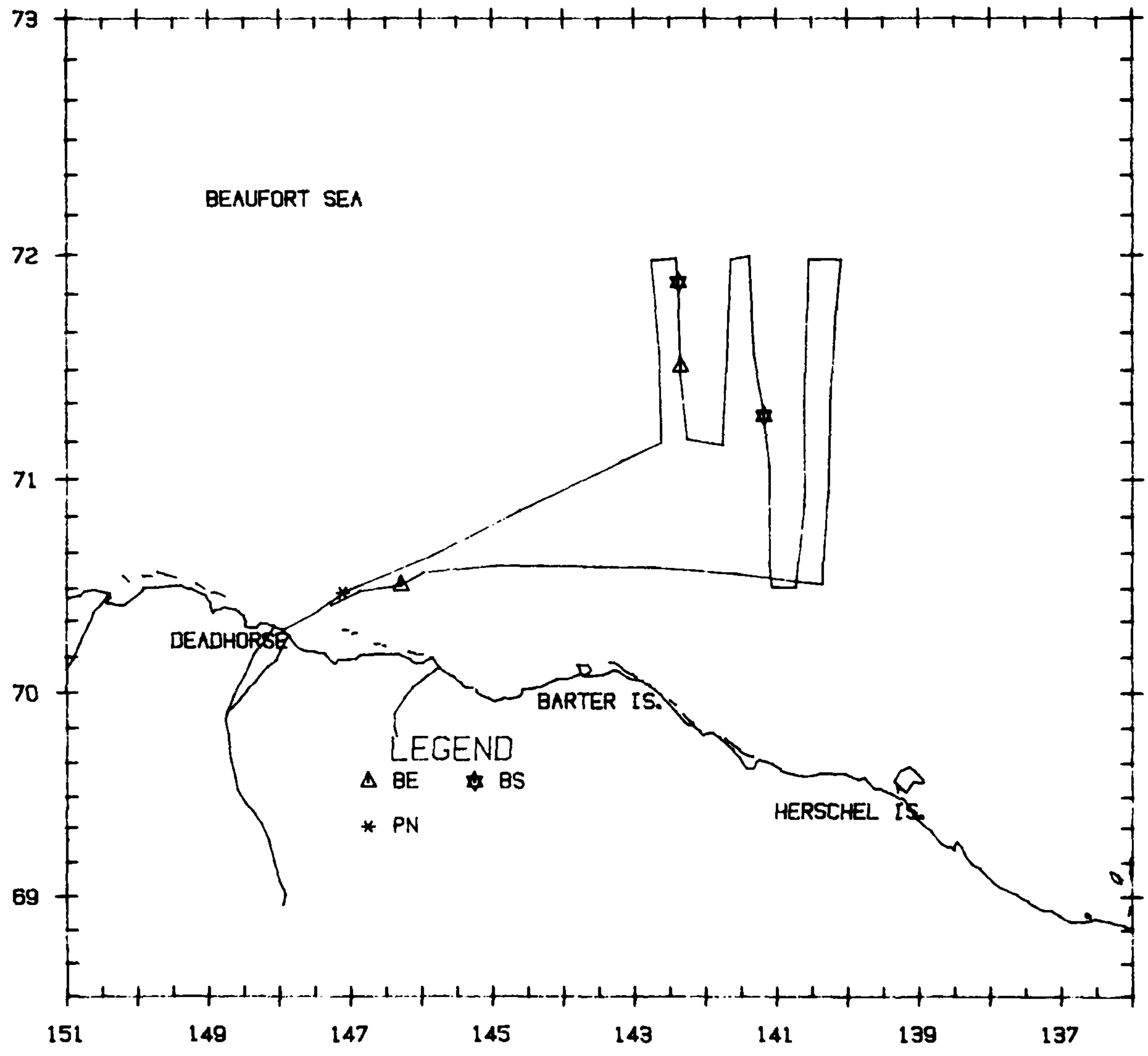
Flight 41: 19 September 1985

Flight was a transect survey of block 8 and the eastern one-half of block 7. Weather was overcast with 5 km to unlimited visibility. Ice coverage ranged from 75 to 95 percent in block 8, and from 5 to 70 percent in block 7. Sea state was Beaufort 00 to 02. Belukha whales, a bearded seal and an unidentified pinniped were seen.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HERSCHEL IS.
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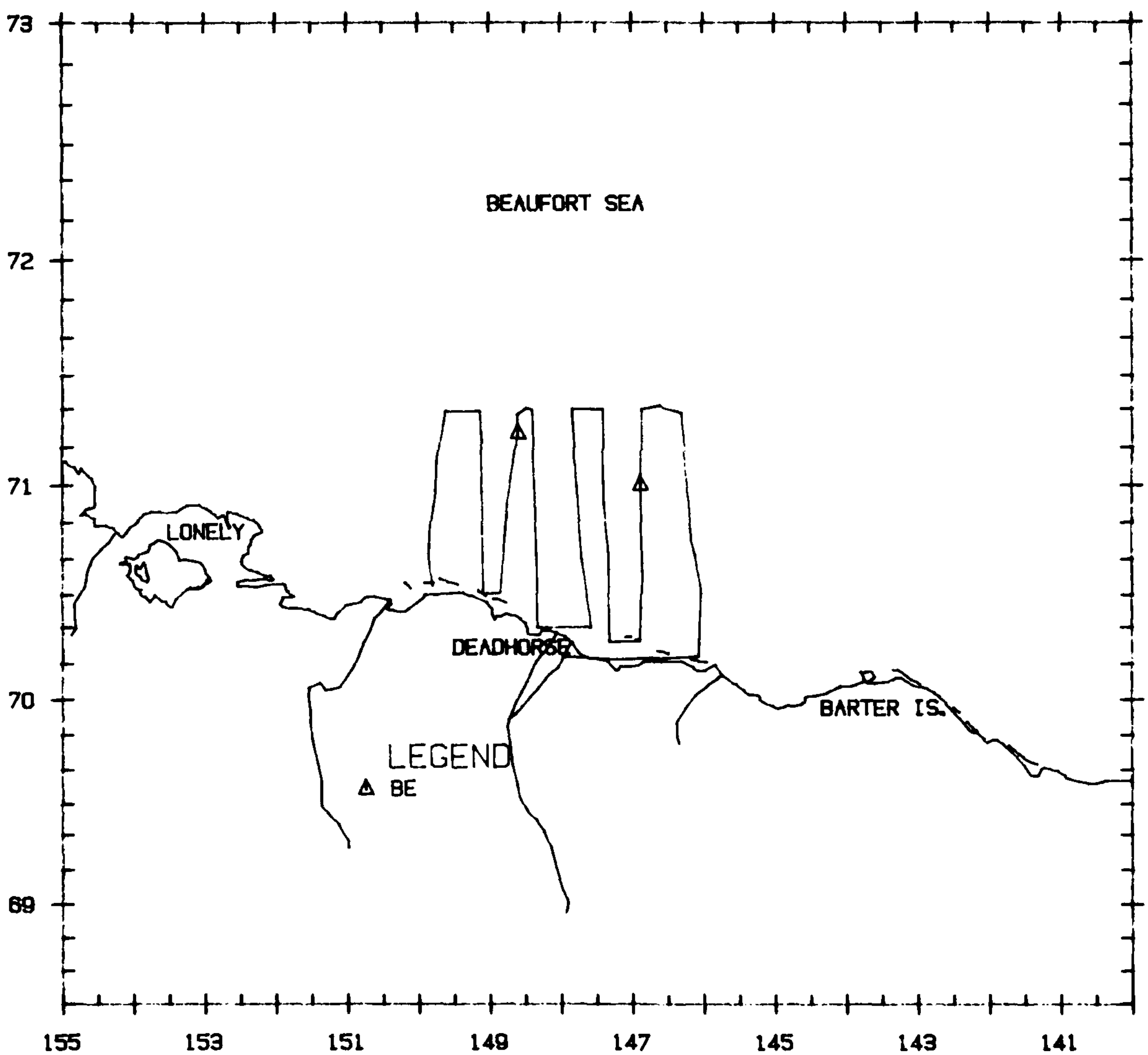
Flight 42: 20 September 1985

Flight was a transect survey of blocks 1 and 2. Weather was low overcast with patches of fog. Visibility ranged from 10 km to unacceptable. Ice coverage was 0 to 75 percent in block 1, and 50 to 80 percent in block 2. Sea state was Beaufort 01 to 05. Belukha whales were the only marine mammals seen.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BEAUFORT SEA
LONELY
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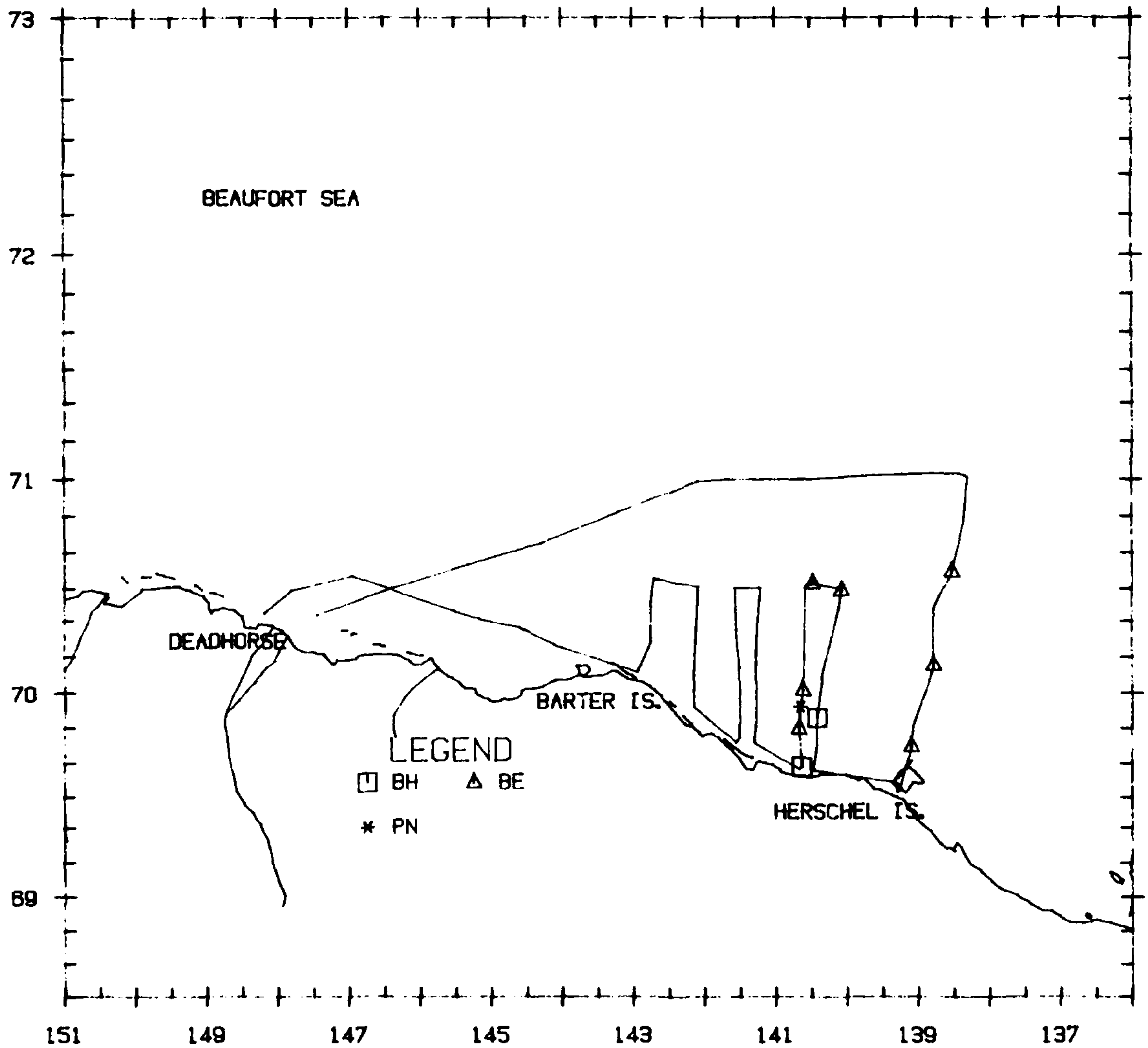
Flight 43: 22 September 1985

Flight was a search survey through block 4, a transect survey of block 5, and a search survey around and north of Herschel Island, then west through block 7. Weather was partly cloudy with some overcast and patchy fog. Visibility was 5 km to unlimited, and sea state was Beaufort 00 to 02. Ice coverage was 5 to 90 percent in blocks 4 and 5, and 40 to 75 percent in block 7. Two bowheads were seen in block 5. Belukha whales and an unidentified pinniped were also seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	69°39.0'	140°38.0'	761	BO	SW	260	5	B0	7
1/0	69°53.1'	140°25.4'	685	BO	SW	270	10	B0	31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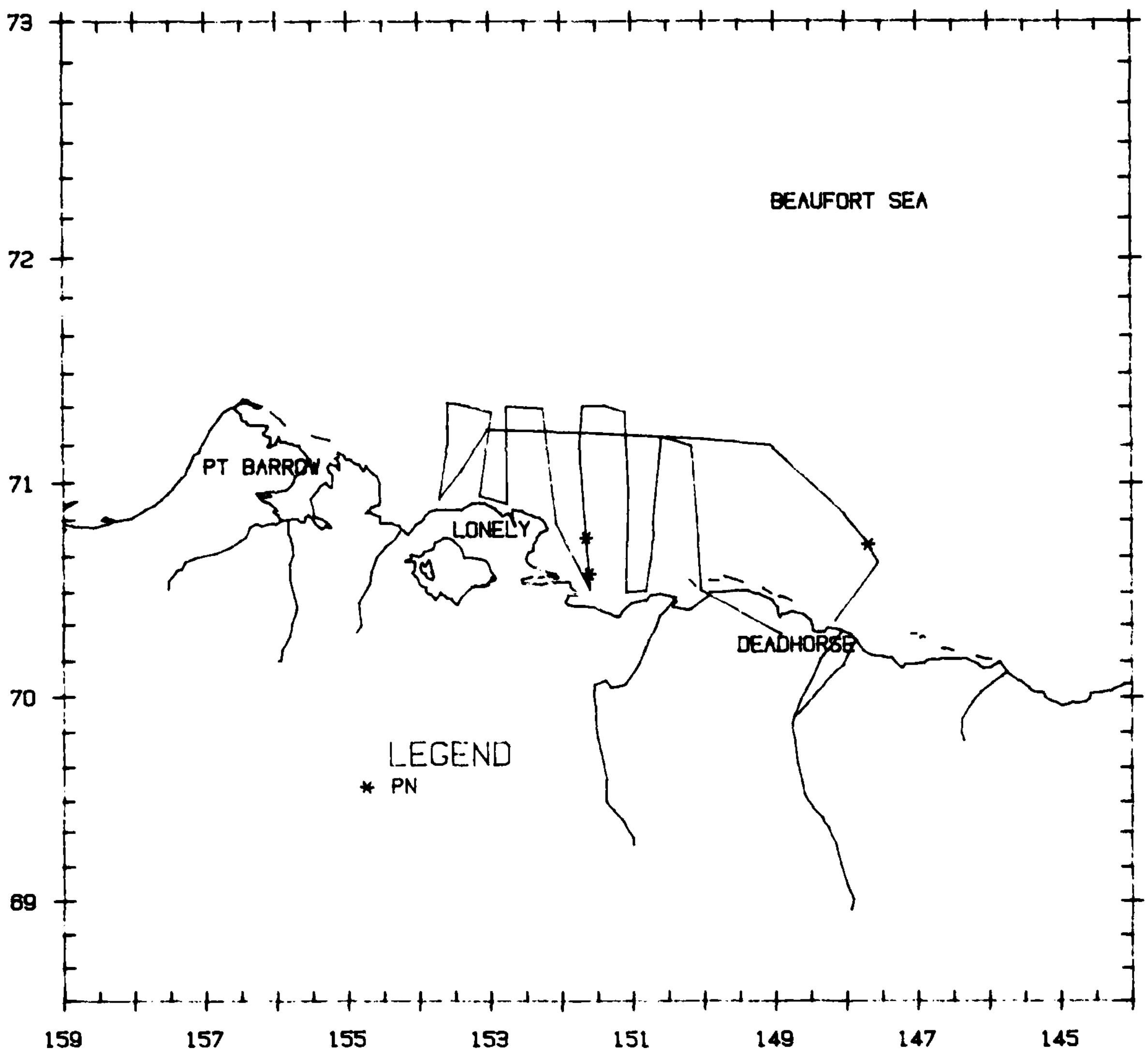
Flight 44: 23 September 1985

Flight was a transect survey of block 3, and a search survey through blocks 1 and 2. Weather was partly cloudy with patches of dense fog that caused the westernmost transect lines to be truncated. Visibility was generally 5 km to unlimited, with localized areas of less than 1 km to unacceptable. Ice coverage was 0 to 5 percent, and sea state was Beaufort 00 to 04. Unidentified pinnipeds were seen.



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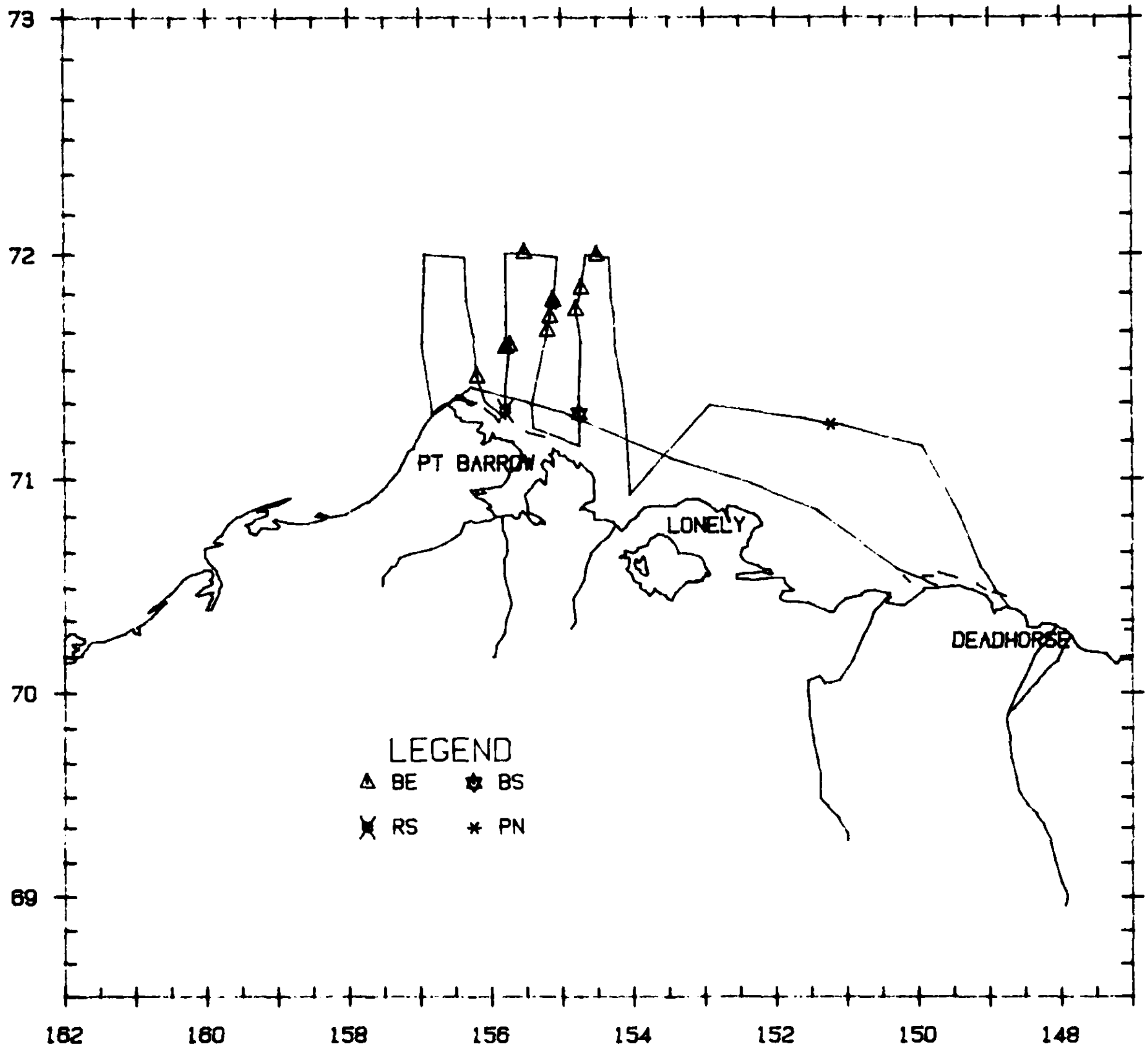
Flight 45: 24 September 1985

Flight was a transect survey of block 12, and a search survey of block 3 and the southwest corner of block 11. Weather ranged from clear to low overcast with patches of fog. Visibility was generally 5 km to unlimited, with some areas of less than 1 km. Sea state was Beaufort 00 to 02. Ice coverage was 0 to 95 percent in block 12, 5 to 25 percent in block 11, and 0 to 20 percent in block 3. Belukha whales, a bearded seal, a ringed seal, and unidentified pinnipeds were seen.



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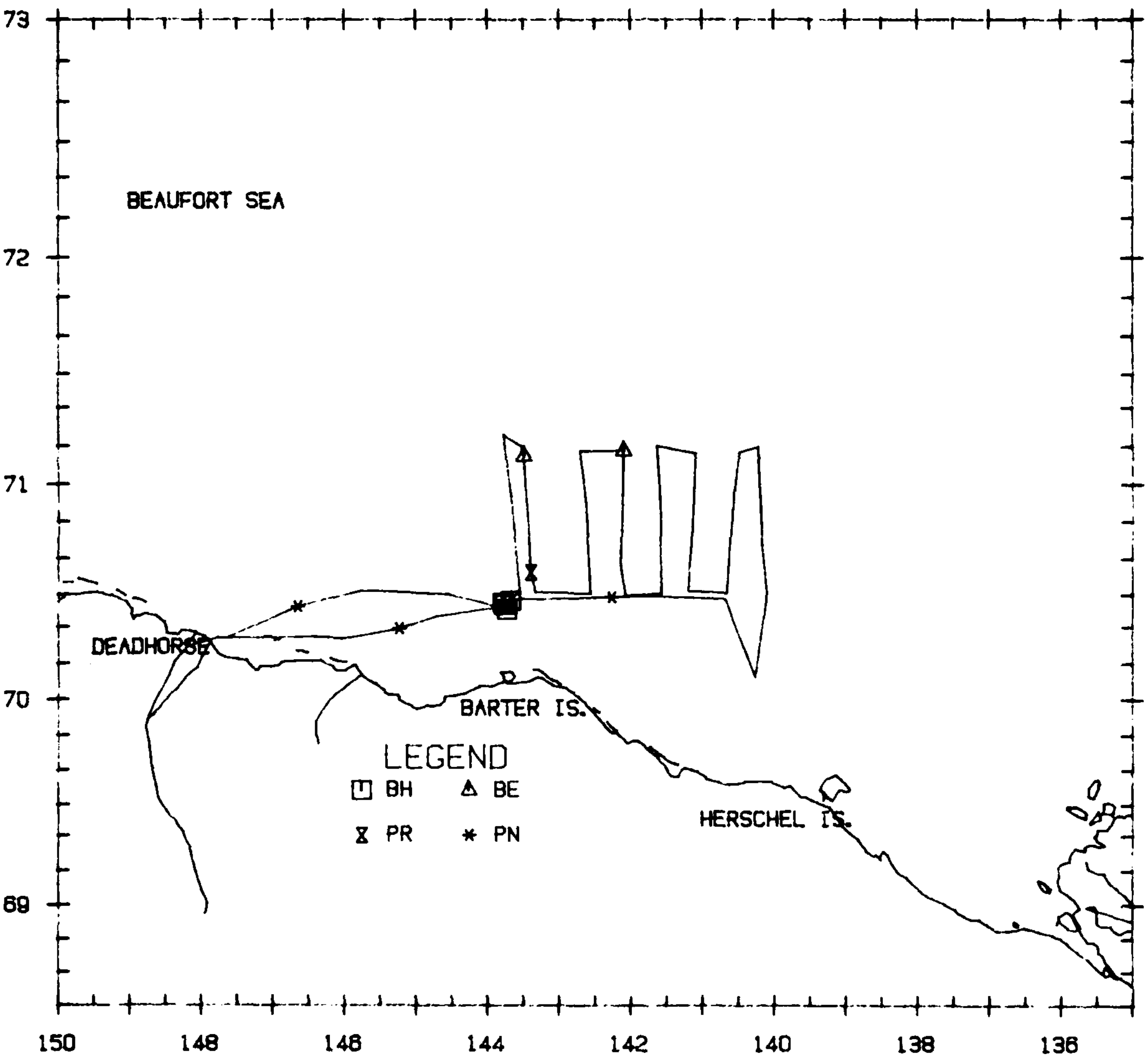
Flight 46: 25 September 1985

Flight was a transect survey of the eastern one-third of block 6, block 7, and a search survey through blocks 4 and 5. Weather ranged from clear to low overcast and fog, with resultant visibility of 3 km to unlimited. Ice coverage was 5 to 90 percent in block 4, and 40 to 90 percent in blocks 5, 6 and 7. Sea state was Beaufort 00 to 02. Seven bowheads were seen in block 4. Belukha whales, a polar bear and unidentified pinnipeds were also seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
2/0	70°26.1'	143°45.2'	--	BO	DI	90	90	B1	40
1/0	70°26.6'	143°46.6'	--	BO	RE	270	90	B1	40
1/0	70°26.5'	143°46.2'	--	BO	RE	120	90	B1	40
2/0	70°27.2'	143°39.8'	781	BO	SW	270	40	B1	37
1/0	70°24.8'	143°43.0'	--	BO	SW	300	35	B1	40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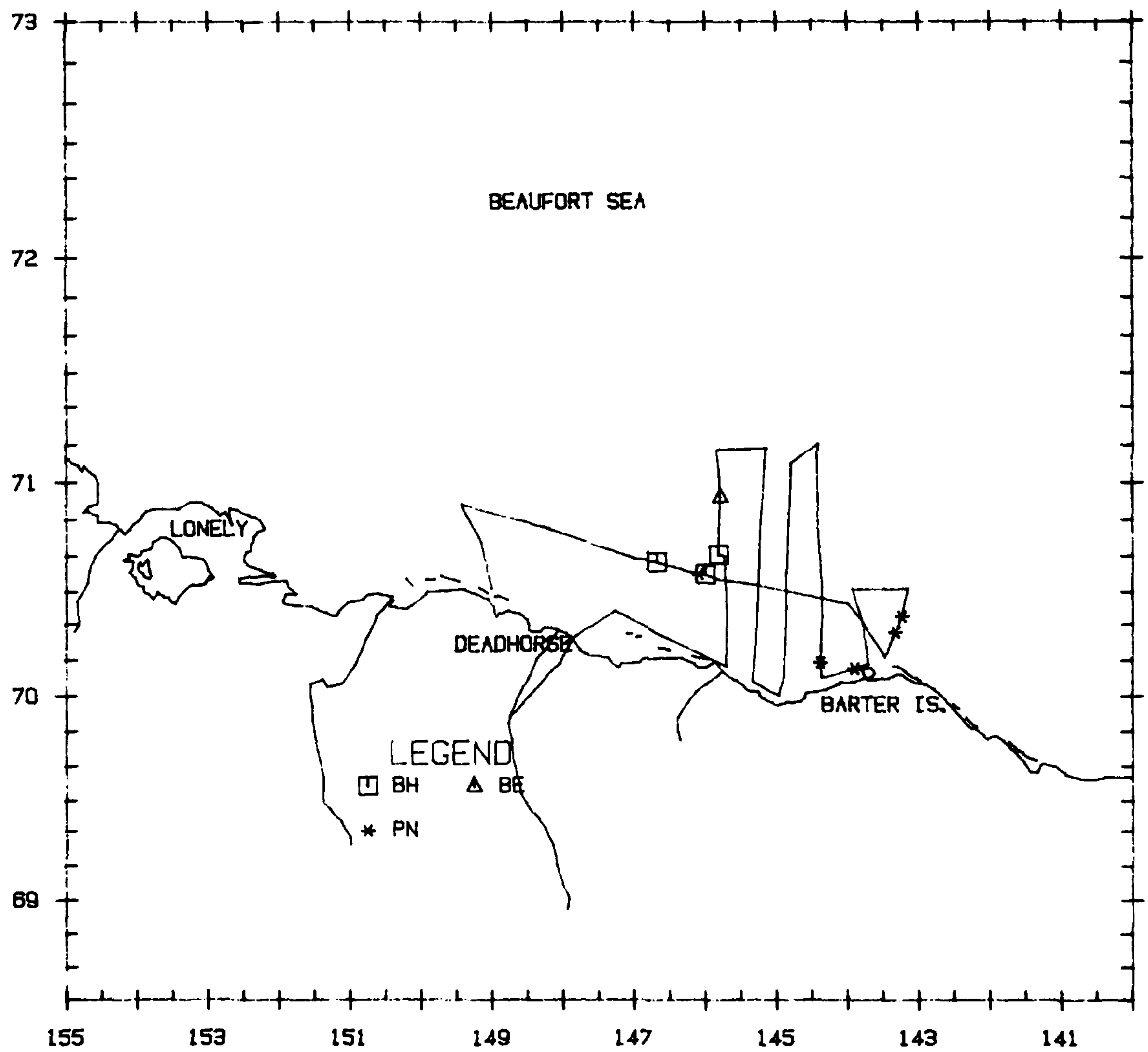
Flight 47: 26 September 1985

Flight was a transect survey of the western two-thirds of block 6, block 4, and a search survey through block 2. Weather was clear and visibility unlimited. Ice ranged from 5 to 90 percent in block 4, from 40 to 95 percent in block 6 and from 0 to 5 percent in block 2. Sea state was Beaufort 00 to 02. Four bowheads, belukhas and unidentified pinnipeds were seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
2/0	70°40.5'	145°48.0'	1072	BW	SW	240	0	B1	57
1/0	70°35.1'	145°59.2'	255	BO	SW	30	0	B1	48
1/0	70°38.6'	146°40.3'	238	SP	SW	240	0	B2	31



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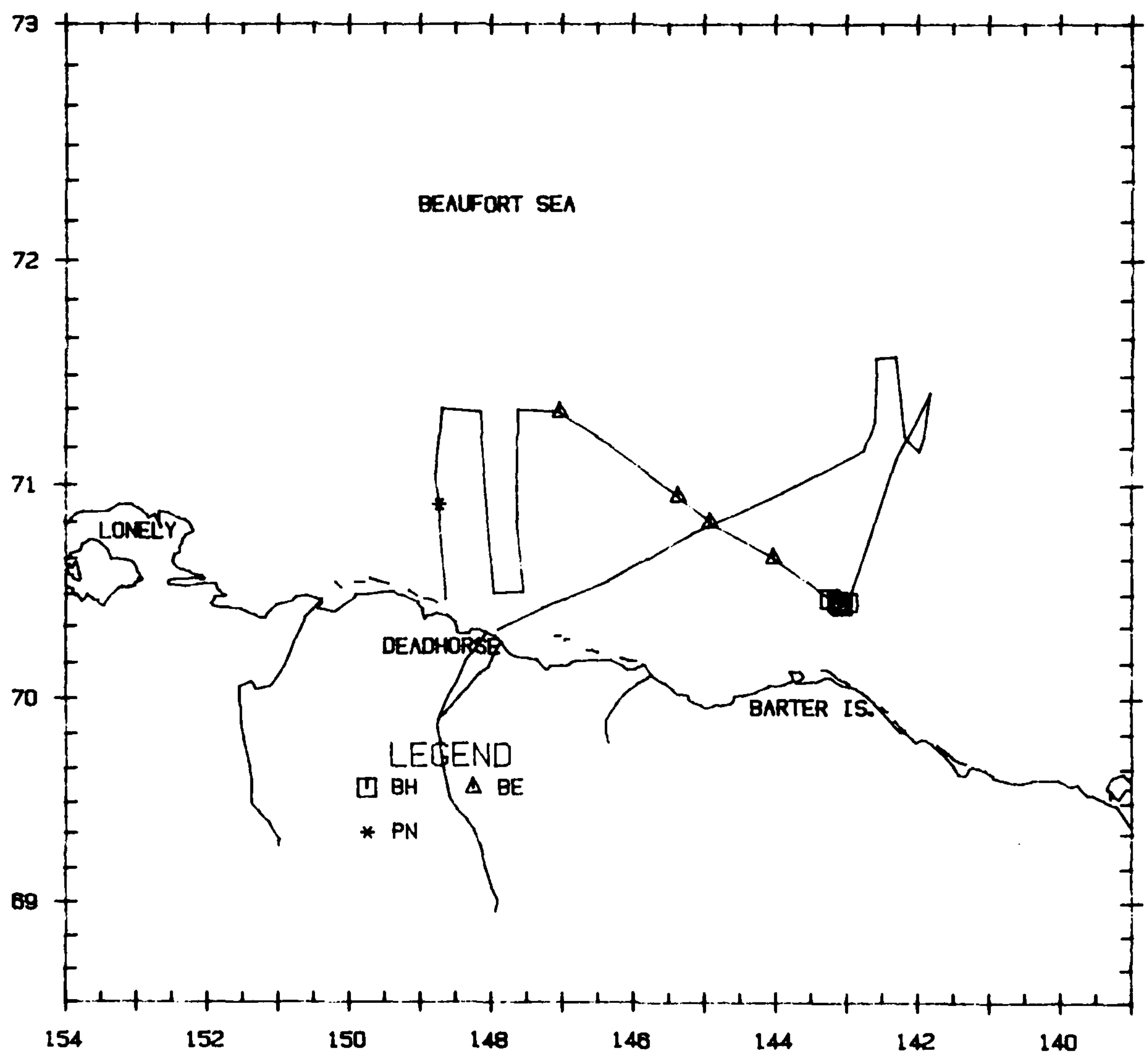
Flight 48: 27 September 1985

Flight was a search survey in blocks 4 and 5 followed by a transect survey in the eastern one-half of blocks 1 and 2, after a transect survey in block 8 was aborted due to fog. Weather was partly cloudy with areas of low fog, and visibility ranged from unlimited to unacceptable. Ice coverage was 0 to 80 percent in blocks 1, 2,and 4; 30 percent in block 5; and 85 to 90 percent in block 8. Sea state ranged from Beaufort 00 to 03. Nineteen bowheads, including three calves, were seen north of Barter Island. Belukha whales and an unidentified pinniped were also seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
3/0	70°26.7'	142°58.9'	--	BO	RE	180	30	B1	46
3/0	70°26.1'	143°05.0'	792	BO	ML	330	30	B1	37
2/1	70°26.7'	143°06.6'	--	BO	SW	330	30	B1	37
3/1	70°27.1'	143°07.7'	--	BO	CC	340	30	B1	37
2/0	70°26.5'	143°04.8'	--	BO	SW	180	30	B1	37
1/0	70°25.9'	143°03.5'	--	BO	SW	240	30	B1	37
5/1	70°27.8'	143°14.0'	981	BO	SW	210	30	B1	37



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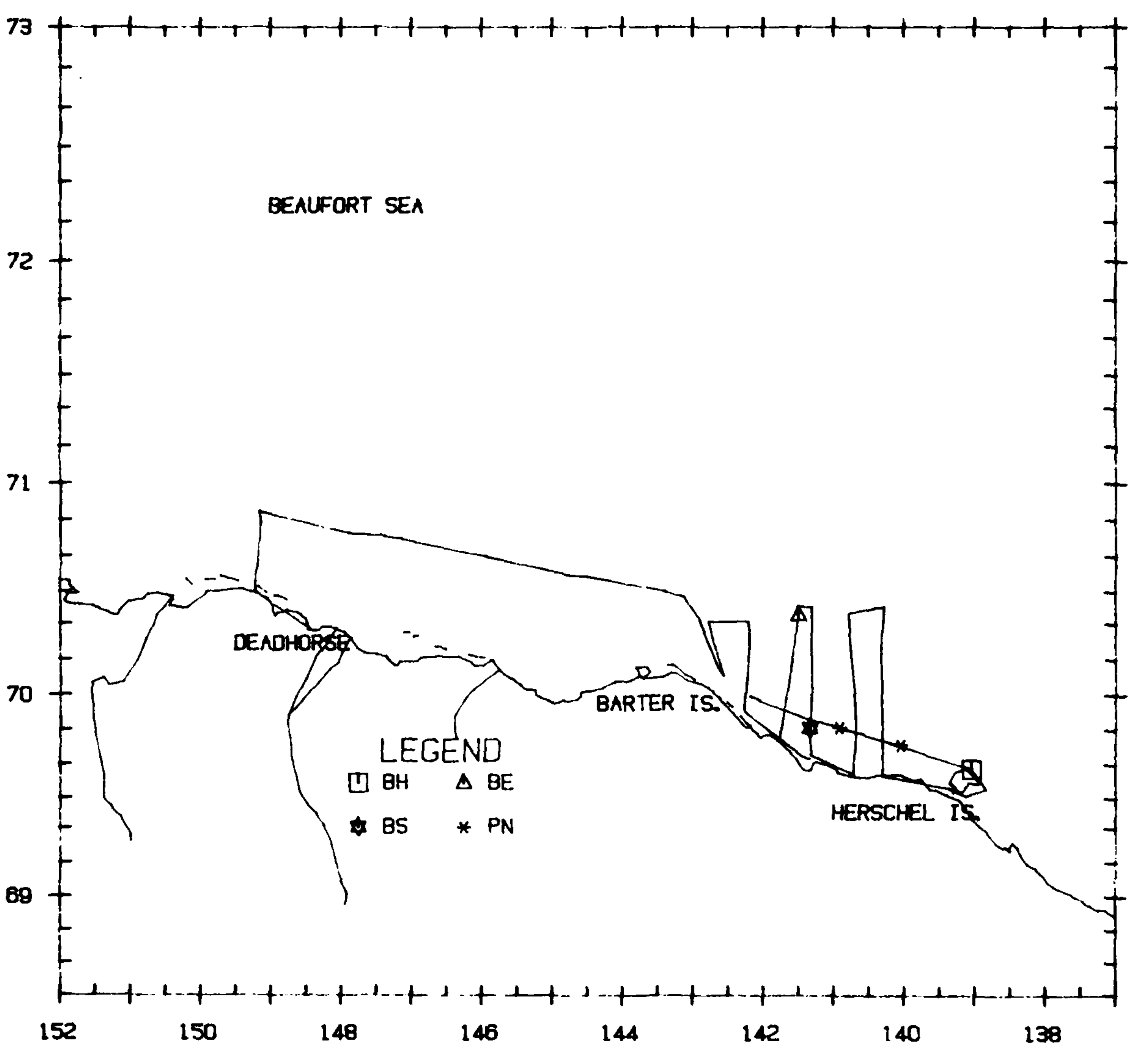
Flight 49: 29 September 1985

Flight was transect survey in block 5 and a search survey to Herschel Island after transect surveys in blocks 1 and 4 were canceled due to heavy low fog. Weather was partly cloudy over most of block 5, with low fog at the northern boundary that caused transect lines to be somewhat truncated. Visibility ranged from 10 km to unacceptable. Ice coverage was 5 to 95 percent, and sea state was Beaufort 00. One bowhead was seen just north of Herschel Island. A belukha whale, a bearded seal,and unidentified pinnipeds were also seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	69°38.5'	139°01.4'	898	BW	SW	60	2	B1	16



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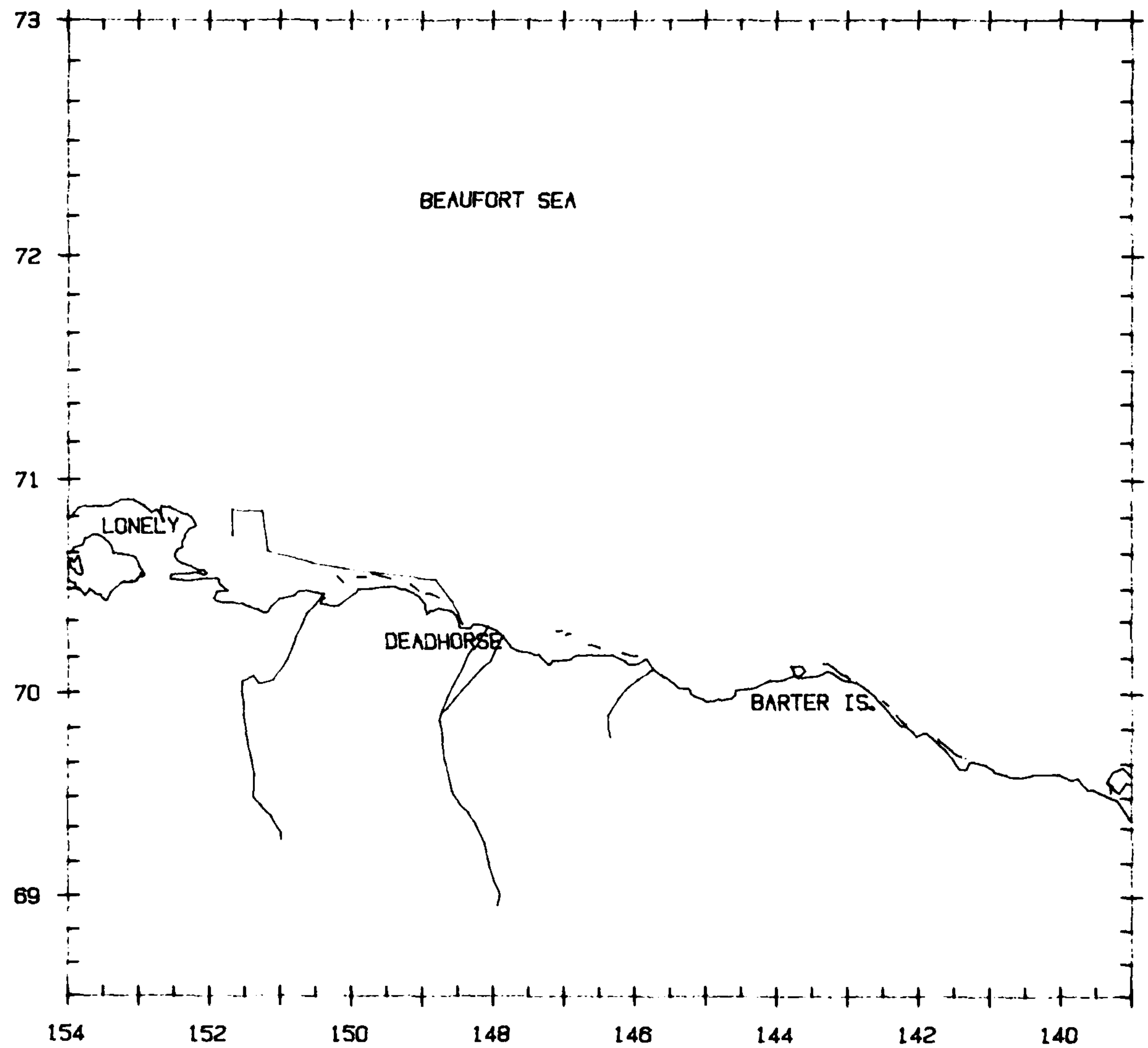
Flight 50: 30 September 1985

Flight was a short search survey in block 1 after a transect survey in block 3 was canceled due to fog and icing conditions. Weather was low overcast with fog and visibility ranged from 3 km to unacceptable. Ice coverage was 0 to 85 percent and sea state was Beaufort 01 to 02. No marine mammals were seen.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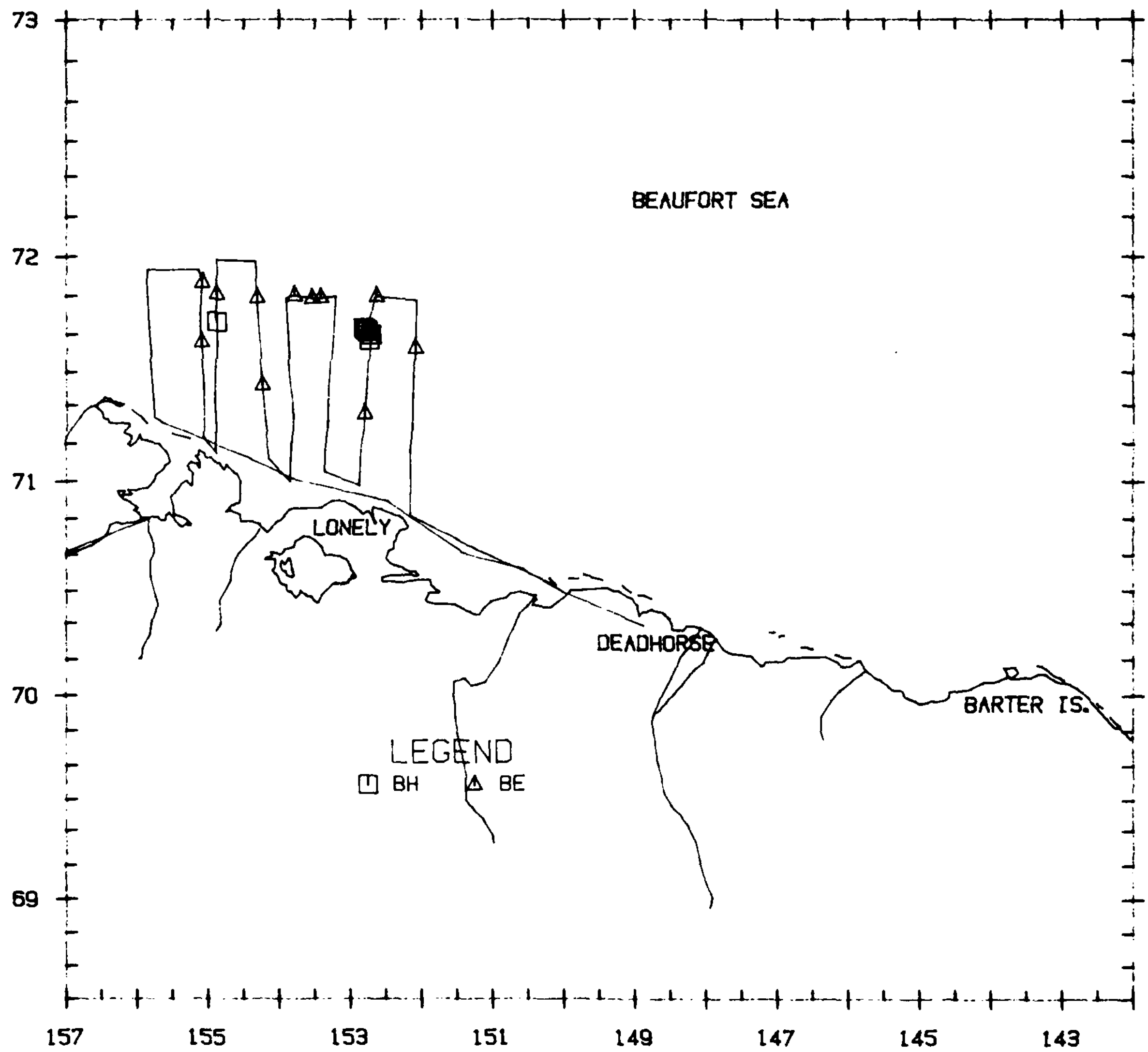
Flight 51: 1 October 1985

Flight was a transect survey of the eastern two-thirds of block 12 and the western one-half of blocks 3 and 11. Weather varied from low overcast to partly cloudy resulting in visibility that ranged from 1 to 10 km. Ice coverage was 0 to 95 percent in block 12, 0 to 10 percent in block 3, and 40 to 90 percent in block 11. Sea state was Beaufort 01 to 03. Nine bowheads were seen; eight of them northeast of Lonely. Belukha whales were also seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°43.3'	154°52.4'	853	BO	RE	240	10	B2	73
2/0	71°39.8'	152°42.4'	707	BO	SW	240	75	B1	46
1/0	71°38.4'	152°44.2'	--	BO	SW	240	75	B1	46
2/0	71°40.7'	152°45.6'	618	BO	RE	150/330	75	B1	177
1/0	71°40.9'	152°45.5'	--	BO	RE	210	75	B1	177
1/0	71°41.2'	152°47.5'	--	BO	SW	280	75	B1	177
1/0	71°41.6'	152°48.7'	--	BO	SW	240	75	B1	177



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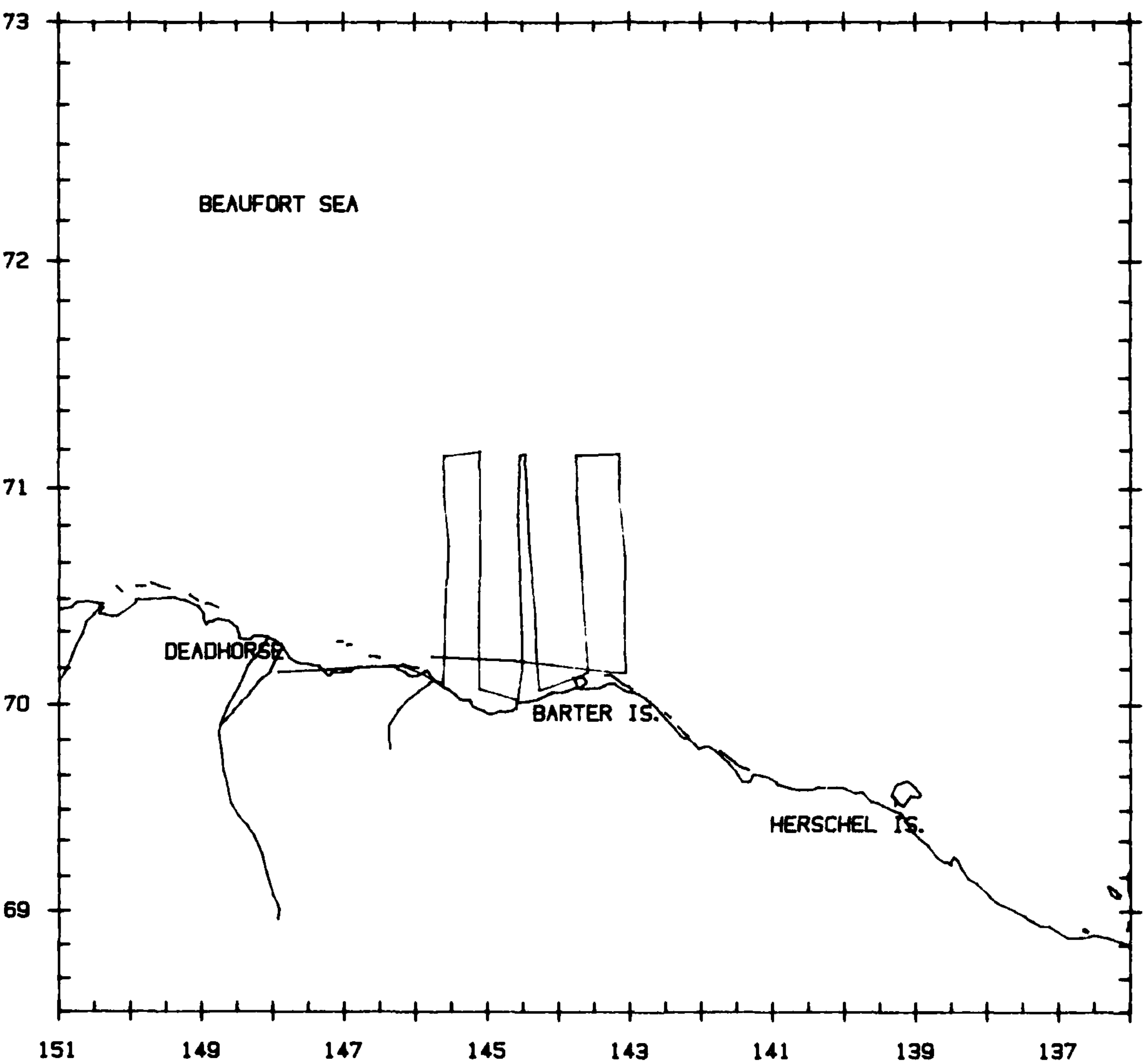
Flight 52: 3 October 1985

Flight was a transect survey of blocks 4 and 6. Weather was overcast with low ceilings and visibility varied from 3 to 10 km. Ice coverage was 10 to 99 percent broken floe and new grease ice and sea state was Beaufort 00 to 02. No marine mammals were seen.


BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
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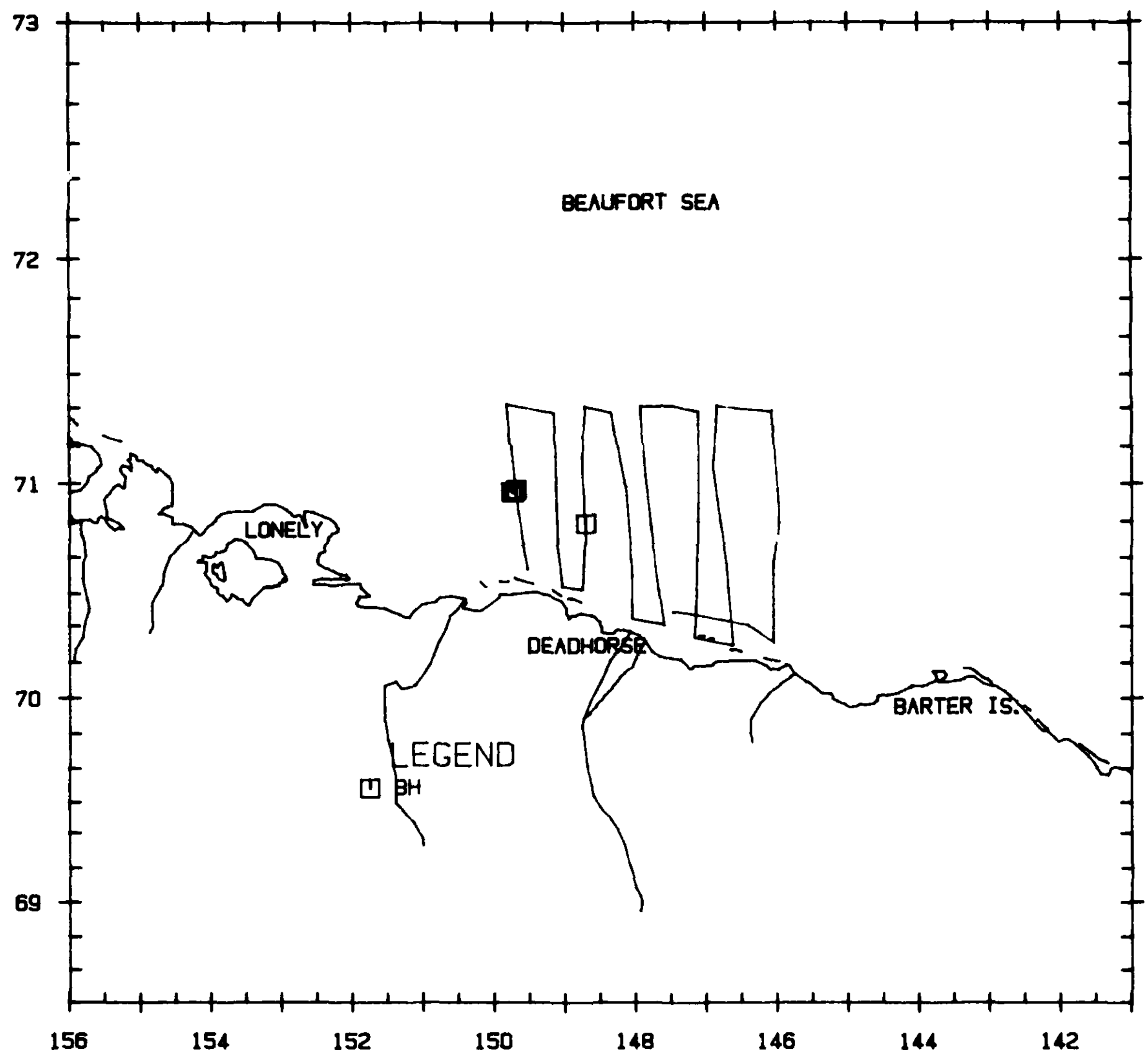
Flight 53: 5 October 1985

Flight was a transect survey of blocks 1 and 2. Weather was clear with unlimited visibility. Ice coverage was 10 to 99 percent broken floe and new grease ice. Sea state was Beaufort 00 to 01. Five bowheads were seen including two that were breaching.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°49.4'	148°42.2'	678	BO	SW	240	20	B1	20
1/0	70°58.6'	149°41.4'	--	BO	BR	240	5	B2	20
2/0	70°57.9'	149°43.2'	--	BO	SW	240	5	B2	20
1/0	70°57.9'	149°45.7'	--	SP	BR	240	5	B2	20



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BEAUFORT SEA
LONELY
DEADHORSE
BARTER IS.
LEGEND
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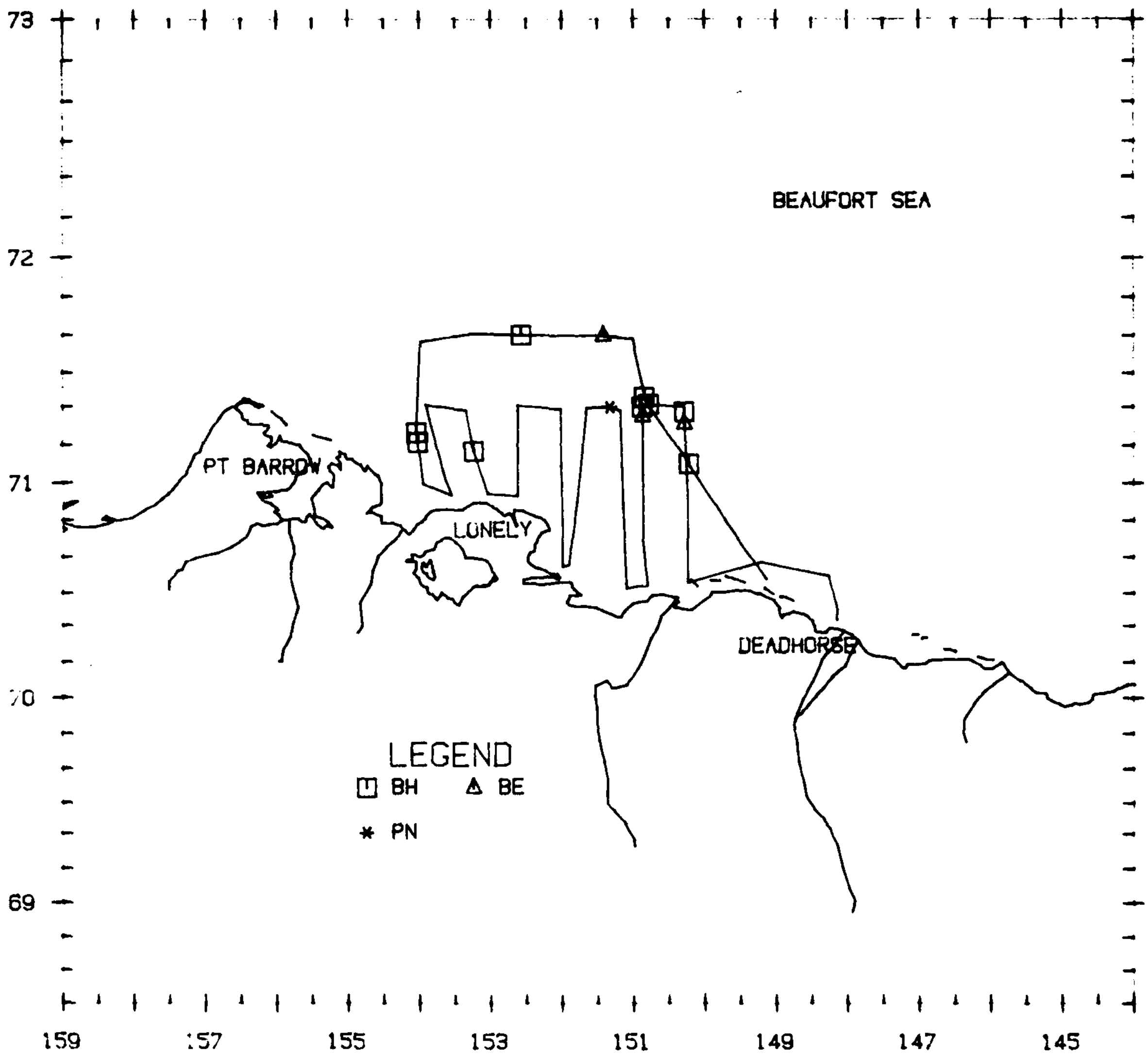
Flight 54: 6 October 1985

Flight was a transect survey of block 3 and a search survey through block 11. Weather was clear to overcast and visibility was unlimited. Ice coverage in the eastern half of the block was 50 to 99 percent and 0 to 5 percent in the western half. Sea state was Beaufort 00 to 02. Twenty-six bowheads were seen. One group of eighteen, including three calves, were milling and possibly feeding. Belukhas and one unidentified pinniped were also seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°18.5'	150°17.5'	655	BO	SW	340	70	B1	225
18/3	71°20.5'	150°47.4'	--	BO	FE	--	80	B1	595
2/0	71°19.8'	150°53.2'	--	BO	SW	240	80	B1	42
1/0	71°08.4'	153°14.7'	474	BO	SW	240	0	B2	7
1/0	71°10.7'	154°0.16'	--	SP	SL	240	0	B2	9
1/0	71°13.2'	154°03.0'	--	DY	SL	--	0	B2	9
1/0	71°40.0'	152°34.4'	1132	BO	SW	240	80	B1	373
1/0	71°04.9'	150°13.7'	509	BO	SW	300	85	B1	16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BEAUFORT SEA
PT BARROW
LONELY
DEADHORSE
LEGEND
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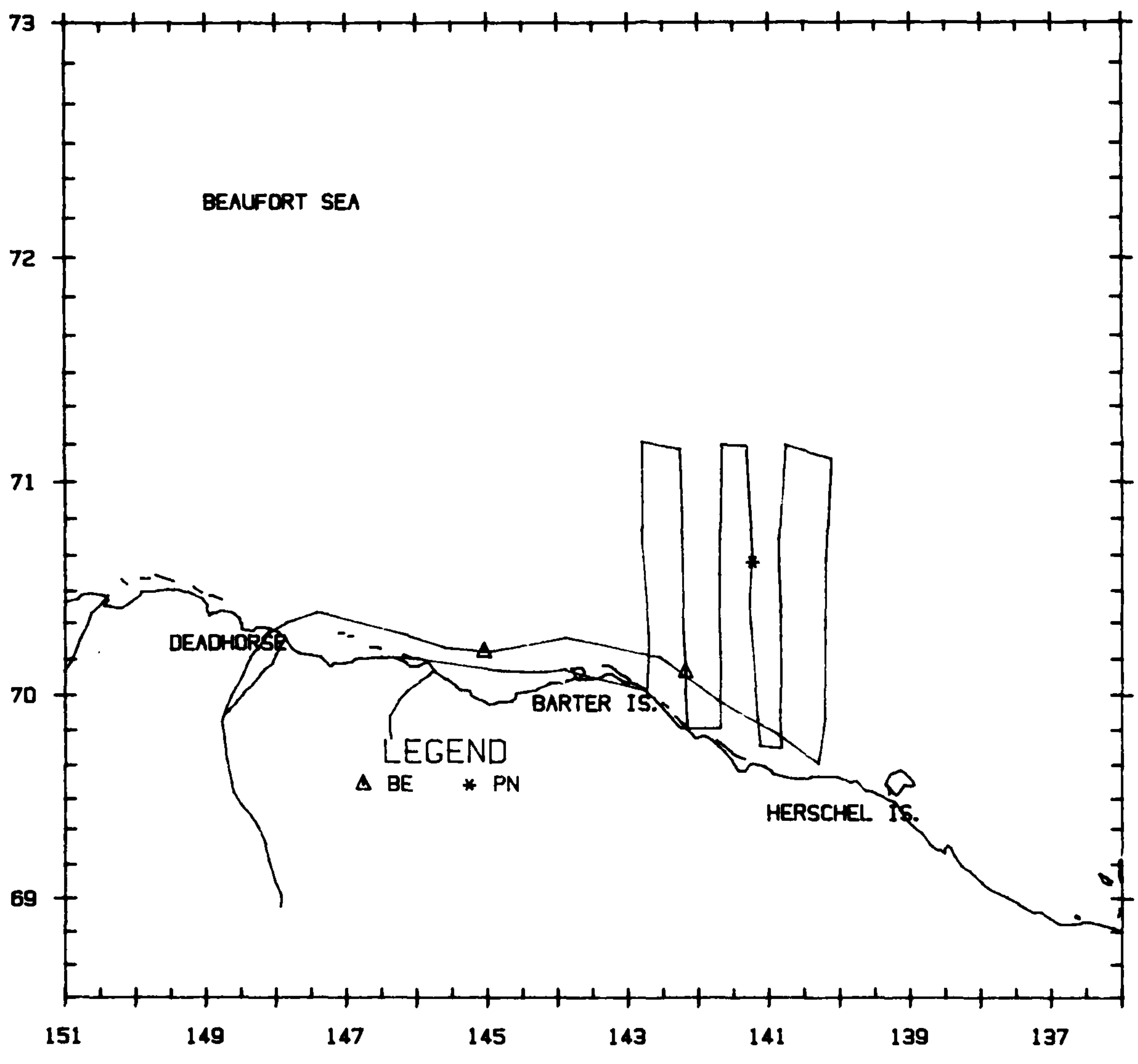
Flight 55: 7 October 1985

Flight was a transect survey of blocks 5 and 7. Weather was overcast with unlimited visibility. Ice coverage in block 5 was 0 to 50 percent with sea state Beaufort 01. Ice coverage in block 7 was 50 to 95 percent with sea state Beaufort 00 to 01. Belukhas and an unidentified pinniped were seen.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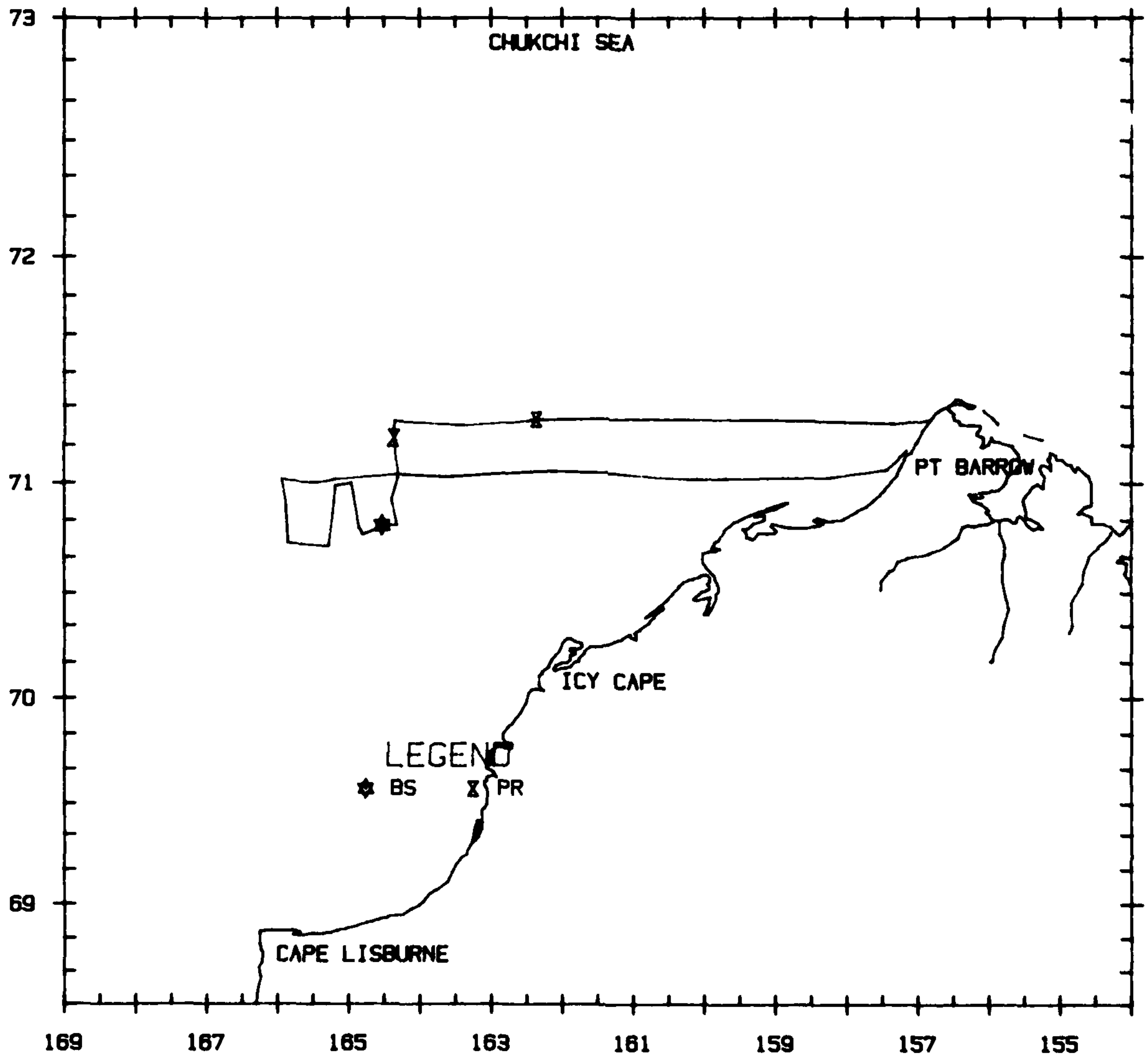
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
▲ BE * PN

Flight 56: 10 October 1985

Flight was a transect survey of block 18 that was aborted due to low ceilings and fog. Visibility was less than 1 km. Ice coverage in the entire area surveyed was variable from 0 to 99 percent and sea state ranged from Beaufort 00 to 04. One bearded seal and two polar bears were seen.



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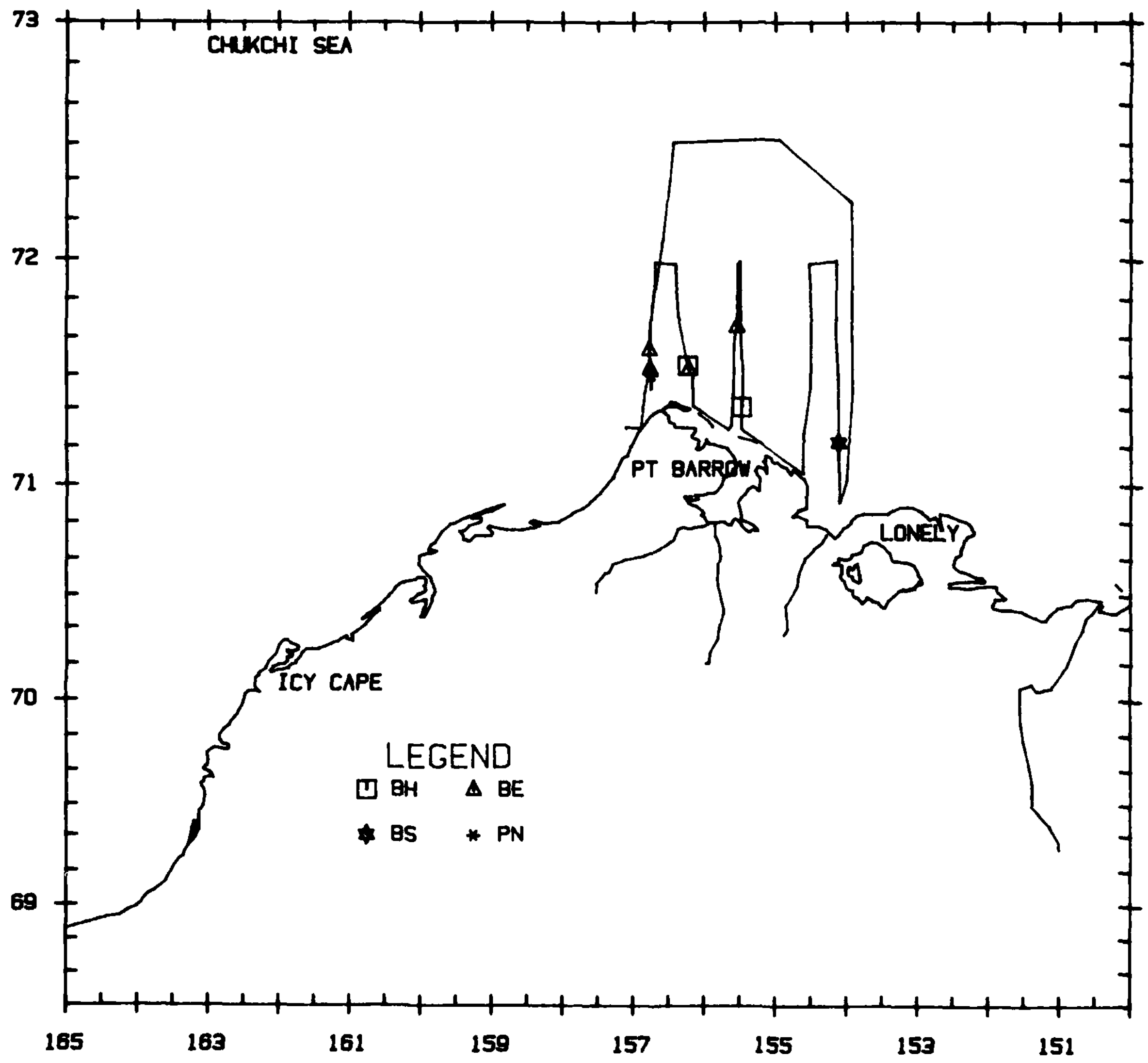
CHUKCHI SEA
PT BARROW
ICY CAPE
LEGEND
BS
PR
CAPE LISBURNE

Flight 57: 11 October 1985

Flight was a transect survey of block 12 and a search survey north along 72°30'N. Weather was overcast with low ceilings and fog and visibility was 3 to 5 km. Ice coverage in southern half of the block was 10 to 55 percent and 75 to 99 percent in the northern half. Sea state was Beaufort 02 to 04. Two bowheads were seen. Belukhas, a bearded seal and an unidentified pinniped were also seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°32.8'	156°13.2'	200	BO	SW	330	10	B3	7
1/0	71°20.6'	155°27.9'	863	BO	MI	30	5	B3	9



CHUKCHI SEA
PT BARROW
LONELY
ICY CAPE
LEGEND
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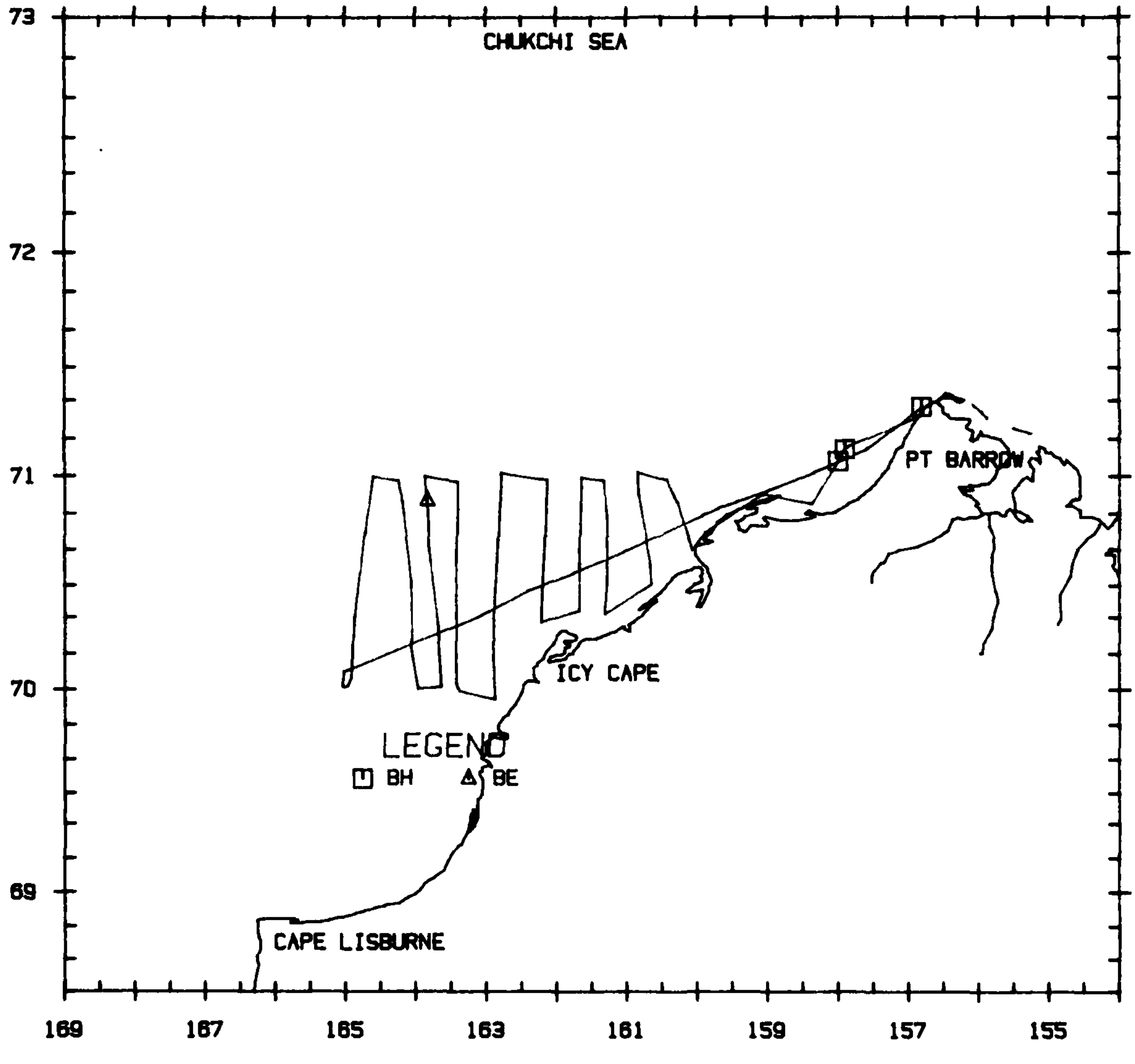
Flight 58: 12 October 1985

Flight was transect survey of block 17 and the eastern one-half of block 18. Weather was overcast with intermittent snow squalls. Visibility varied from unacceptable to 10 km. Sea state was Beaufort 04 and there was no ice. Three bowheads and belukhas were seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°07.3'	157°53.9'	--	BO	SW	060	0	B2	22
1/0	71°04.1'	157°59.6'	249	BO	DI	--	0	B2	27
1/0	71°18.5'	156°48.0'	--	SP	SW	190	O	B3	18


CHUKCHI SEA
PT BARROW
ICY CAPE
LEGEND
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CAPE LISBURNE
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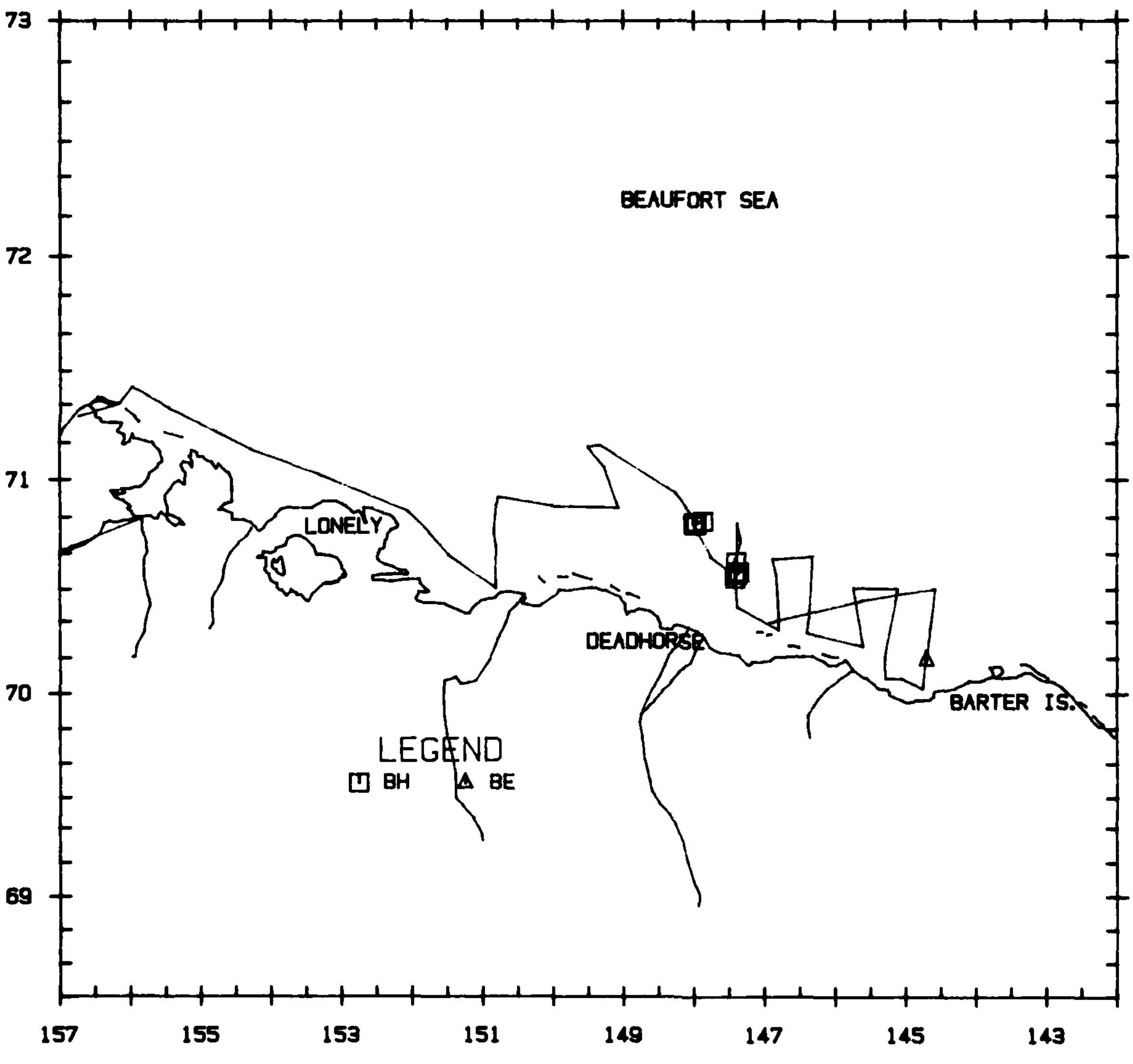
Flight 59: 13 October 1985

Flight was a transect survey of the eastern one-half of block 1 and western one-half of block 4. Weather in these areas was clear with unlimited visibility, although low-lying fog covered the rest of the Alaskan Beaufort Sea. Ice coverage was 90 to 99 percent and sea state varied from Beaufort 00 to 01. Thirteen bowheads were seen, mostly swimming slowly west. One belukha was also seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	70°48.3'	147°57.4'	--	BW	RE	340	99	B0	38
1/0	70°48.1'	147°58.7'	--	BO	SW	210	99	B0	38
2/0	70°49.1'	147°51.2'	--	BO	SW	210	95	B0	38
1/0	70°48.9'	147°59.2'	--	BO	SW	250	95	B0	38
1/0	70°48.2'	147°59.9'	--	BO	SW	250	95	B0	38
1/0	70°38.0'	147°23.2'	766	BO	SW	210	99	B0	38
1/0	70°34.5'	147°22.4'	1650	BO	SW	210	99	B0	18
4/0	70°35.1'	147°20.7'	--	BO	SW	180	99	B0	38
1/0	70°33.5'	147°24.2'	--	BO	RE	--	95	B0	18



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BEAUFORT SEA
LONELY
DEADHORSE
BARTER IS.
LEGEND
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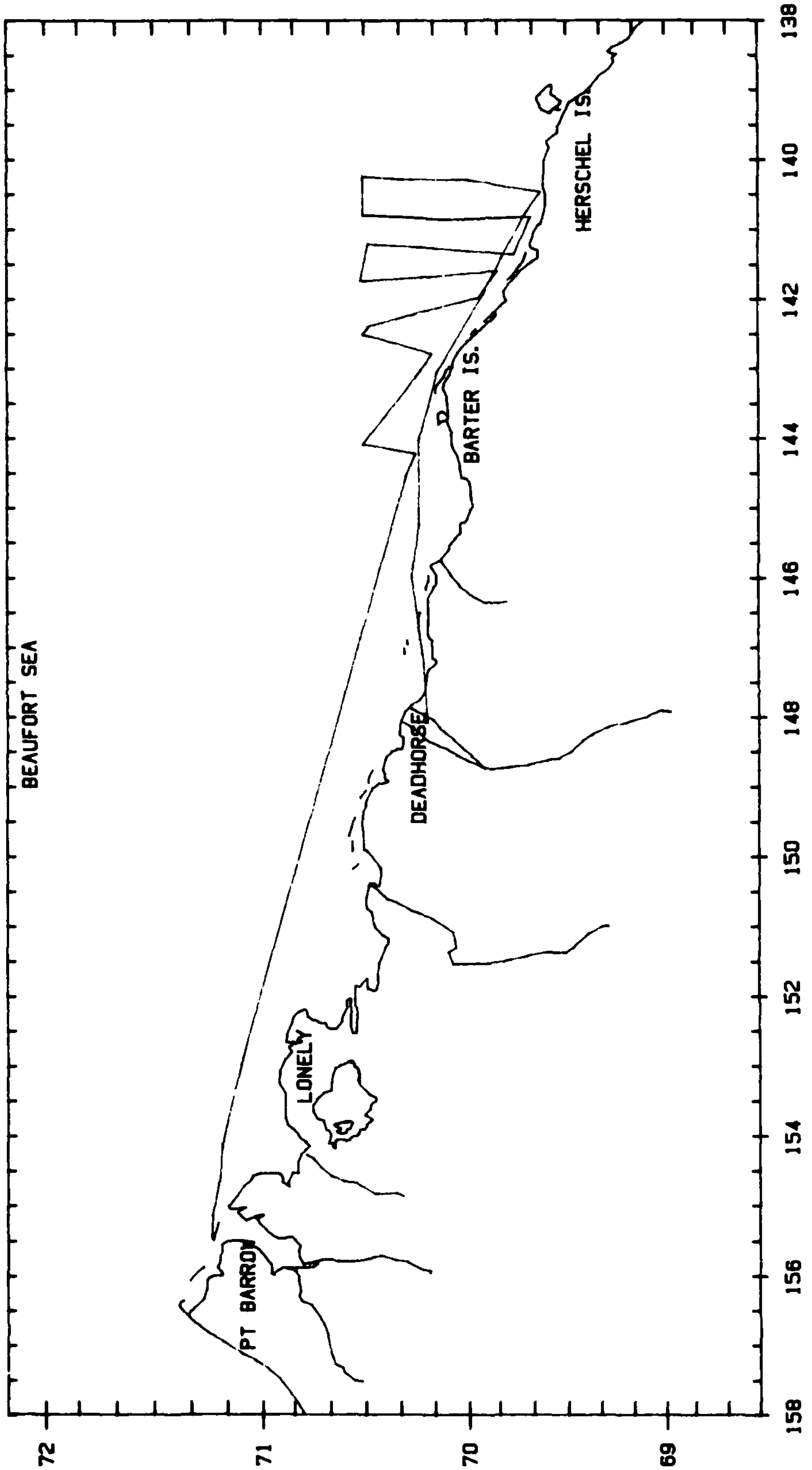
Flight 60: 14 October 1985

Flight was a transect survey of block 5 and the western one-half of block 4. Weather was overcast with fog and high winds (>50 knots). Visibility varied from 10 km to unacceptable. Ice coverage was 90 to 99 percent and sea state ranged from Beaufort 00 to 03. No marine mammals were seen.



BEAUFORT SEA
PT BARROW
LONELY
DEADHORSE
BARTER IS.
HERSCHEL IS.
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Flight 61: 15 October 1985

Flight was a search survey through the northeastern Chukchi Sea after low ceilings and low visibility forced an attempted survey of blocks 18 and 19 to be aborted. Ice coverage varied from 0 to 99 percent and sea state was Beaufort 00 to 04. One bowhead was seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°12.5'	160°29.2'	240	BO	SW	30	0	B3	37

AD-A172 753 AERIAL SURVEYS OF ENDANGERED WHALES IN THE NORTHERN BERING EASTERN CHUKCH.. (U) NAVAL OCEAN SYSTEMS CENTER SAN DIEGO CA D K LJUNGBLAD ET AL. AUG 86 NOSC/TR-1111 4/5

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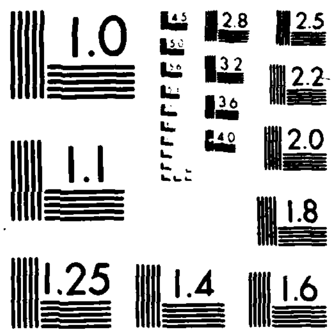
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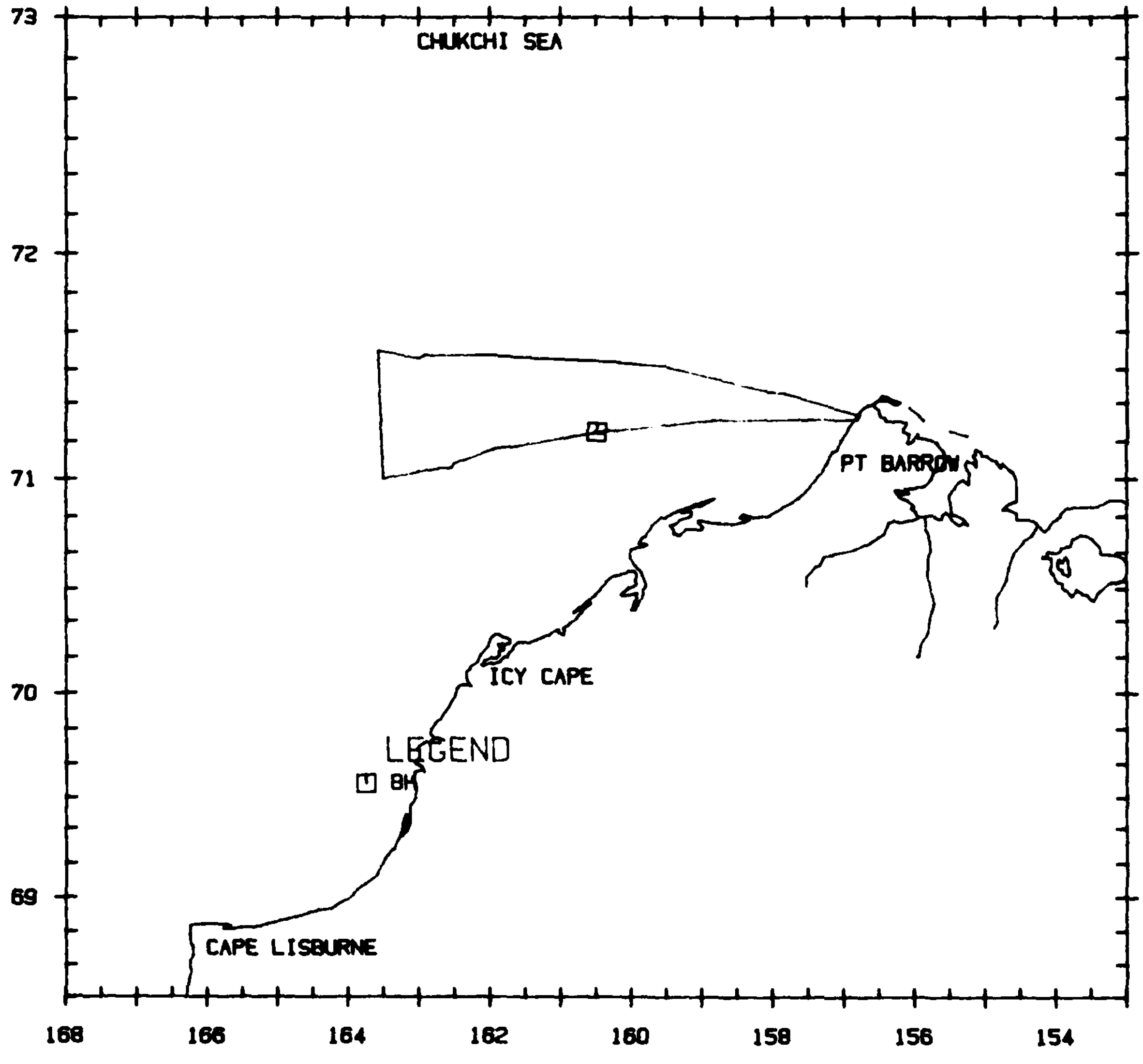

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CHUKCHI SEA
PT BARROW
ICY CAPE
LEGEND
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CAPE LISBURNE
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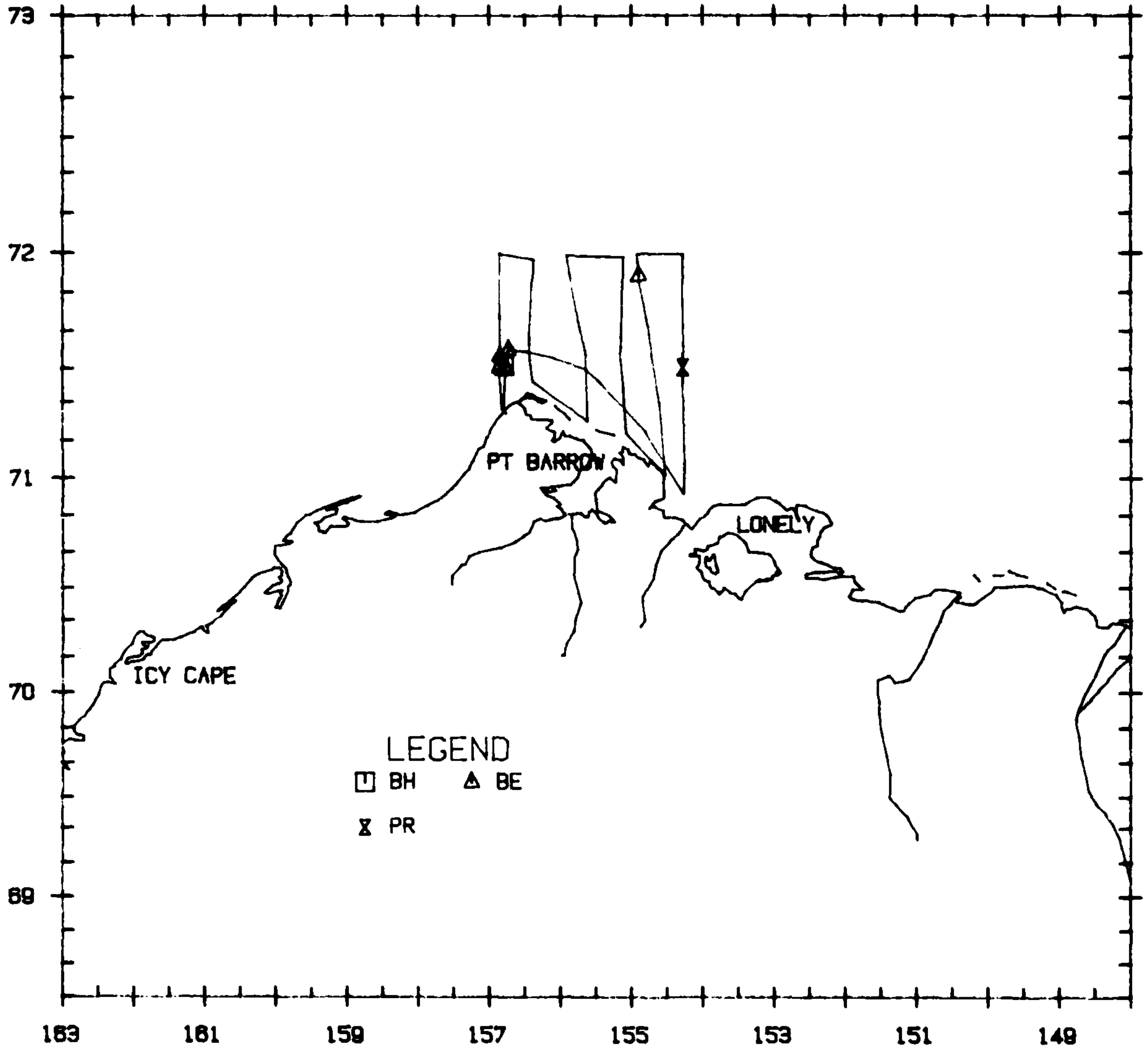
Flight 62: 16 October 1985

Flight was a transect survey of block 12. Weather was clear to overcast and visibility was unlimited. Ice coverage varied from 0 to 95 percent and sea state was Beaufort 00 to 03. One bowhead was seen swimming south. Belukhas and polar bears were also seen.

T#/C#	LAT	LONG	DIS	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	71°30.7'	156°47.0'	333	BO	SW	150	0	B3	145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PT BARROW
LONELY
ICY CAPE
LEGEND
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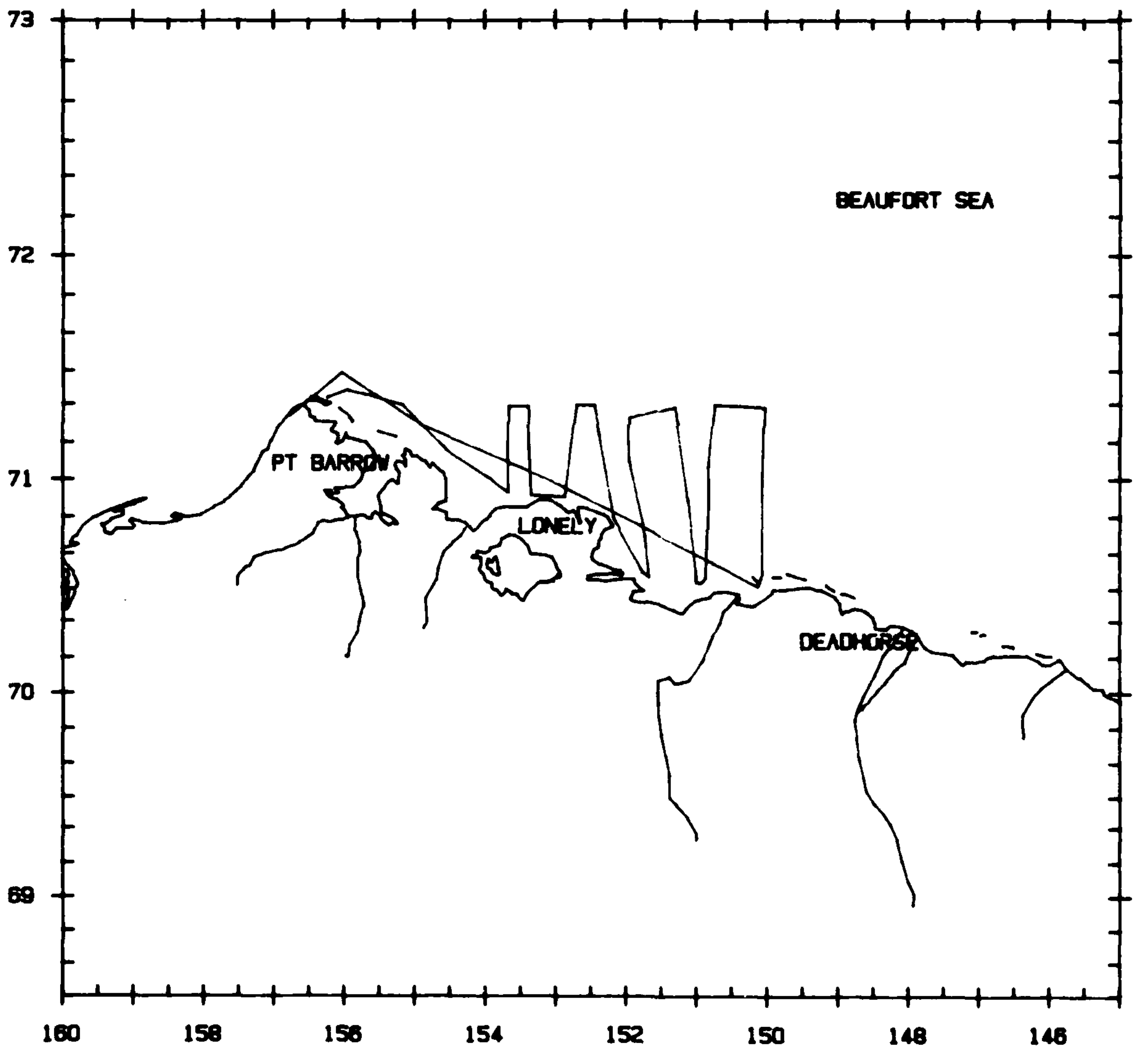
Flight 63: 17 October 1985

Flight was a transect survey of block 3. Weather was overcast with visibility varying from 5 km to unlimited. Ice coverage was 95 to 99 percent and sea state ranged from Beaufort 00 to 01. No marine mammals were seen.



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BEAUFORT SEA
PT BARROW
LONELY
DEADHORSE
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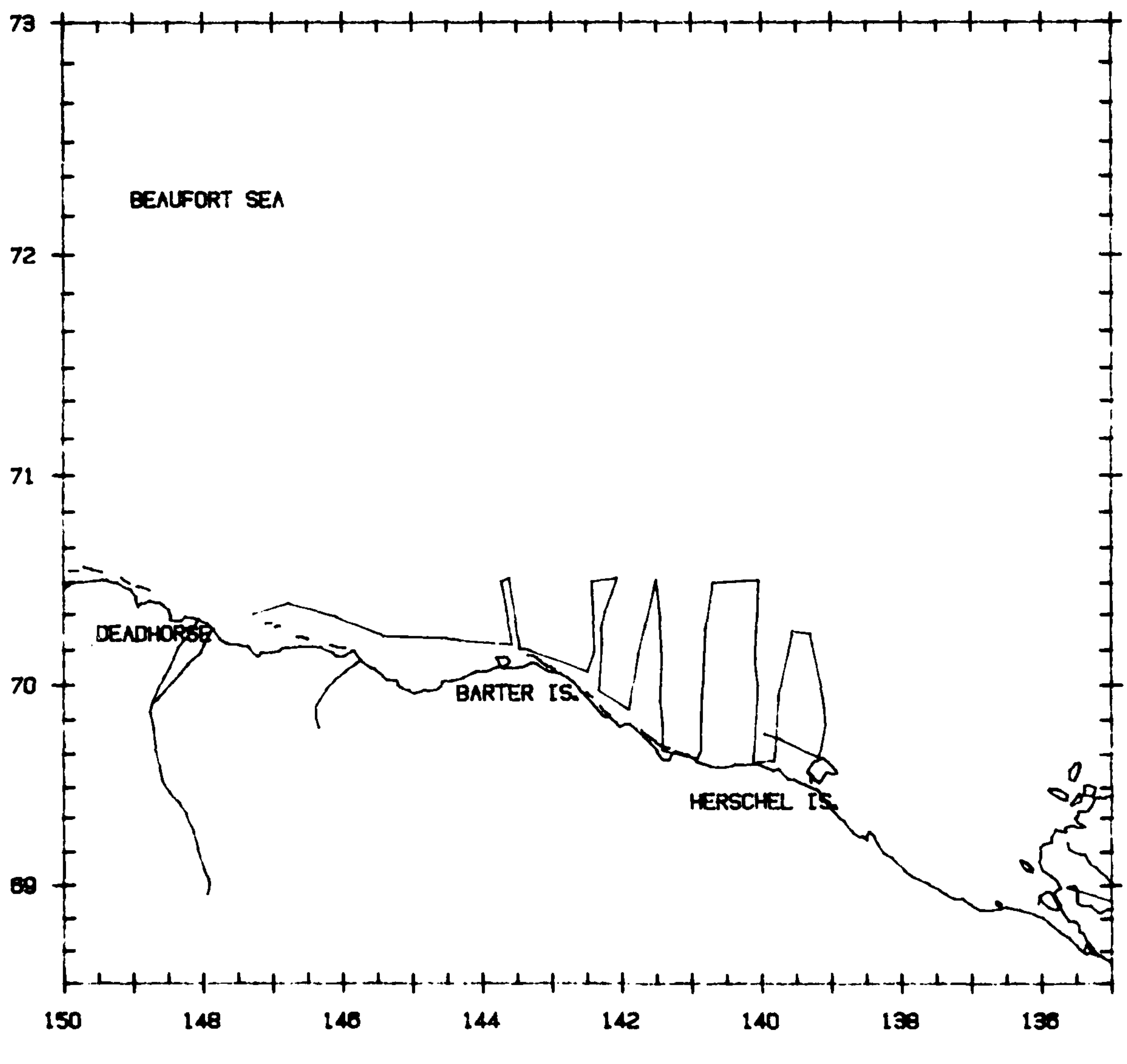
Flight 64: 19 October 1985

Flight was a transect survey of Canada between 139°W and 140°W, block 5 and the eastern one-third of block 4. Weather was overcast with fog and visibility varied from less than 1 km near-shore to unlimited offshore. Ice coverage was 99 percent and sea state ranged from Beaufort 00 to 03. No marine mammals were seen.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BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
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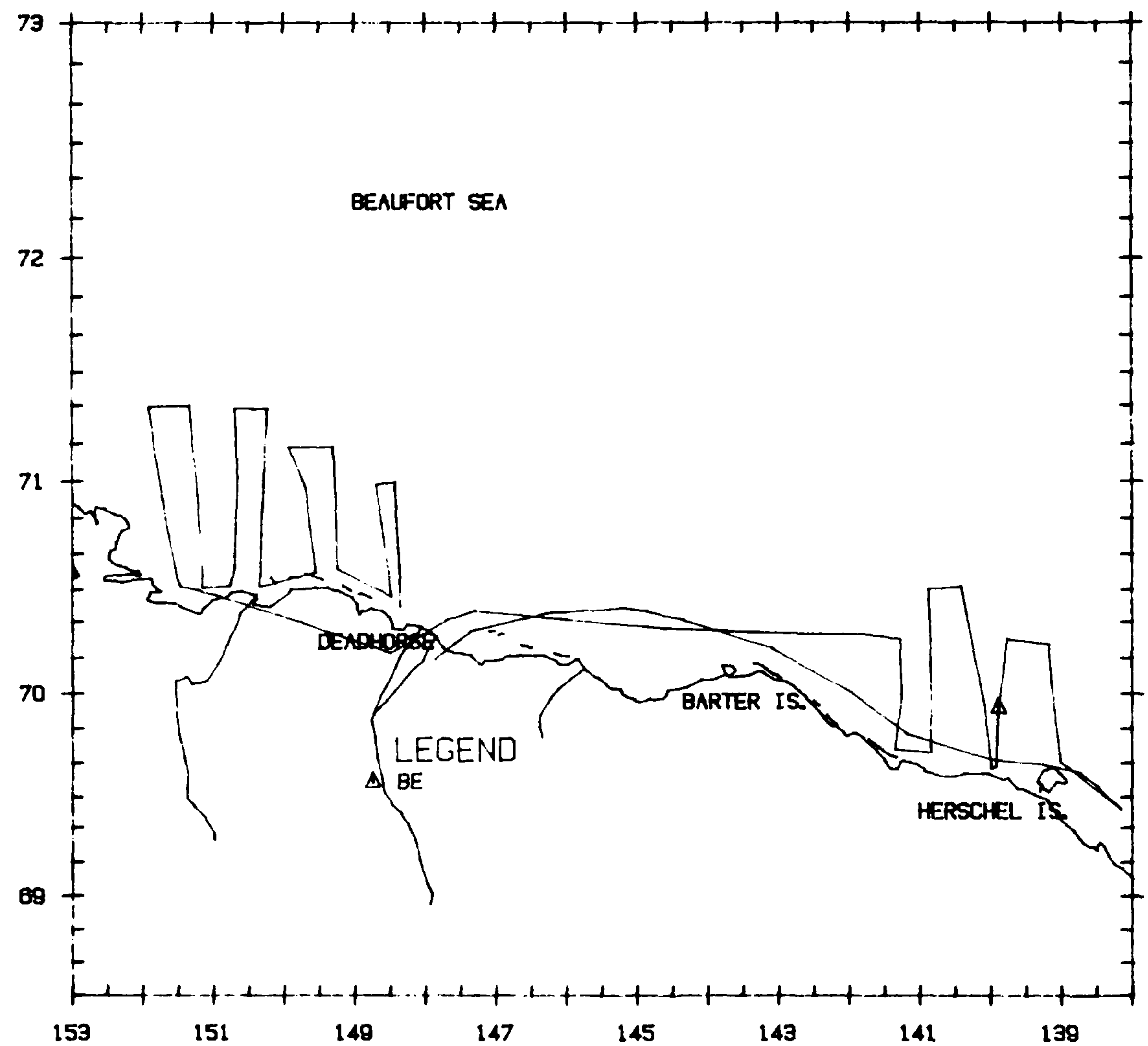
Flight 65: 20 October 1985

Flight was a transect survey of parts of blocks 5, 3 and 1 and a search survey east to 138°10'W. Weather was overcast to clear with unlimited visibility. Ice coverage in all areas was 95 to 99 percent and sea state was Beaufort 00 to 01. Belukhas were seen.



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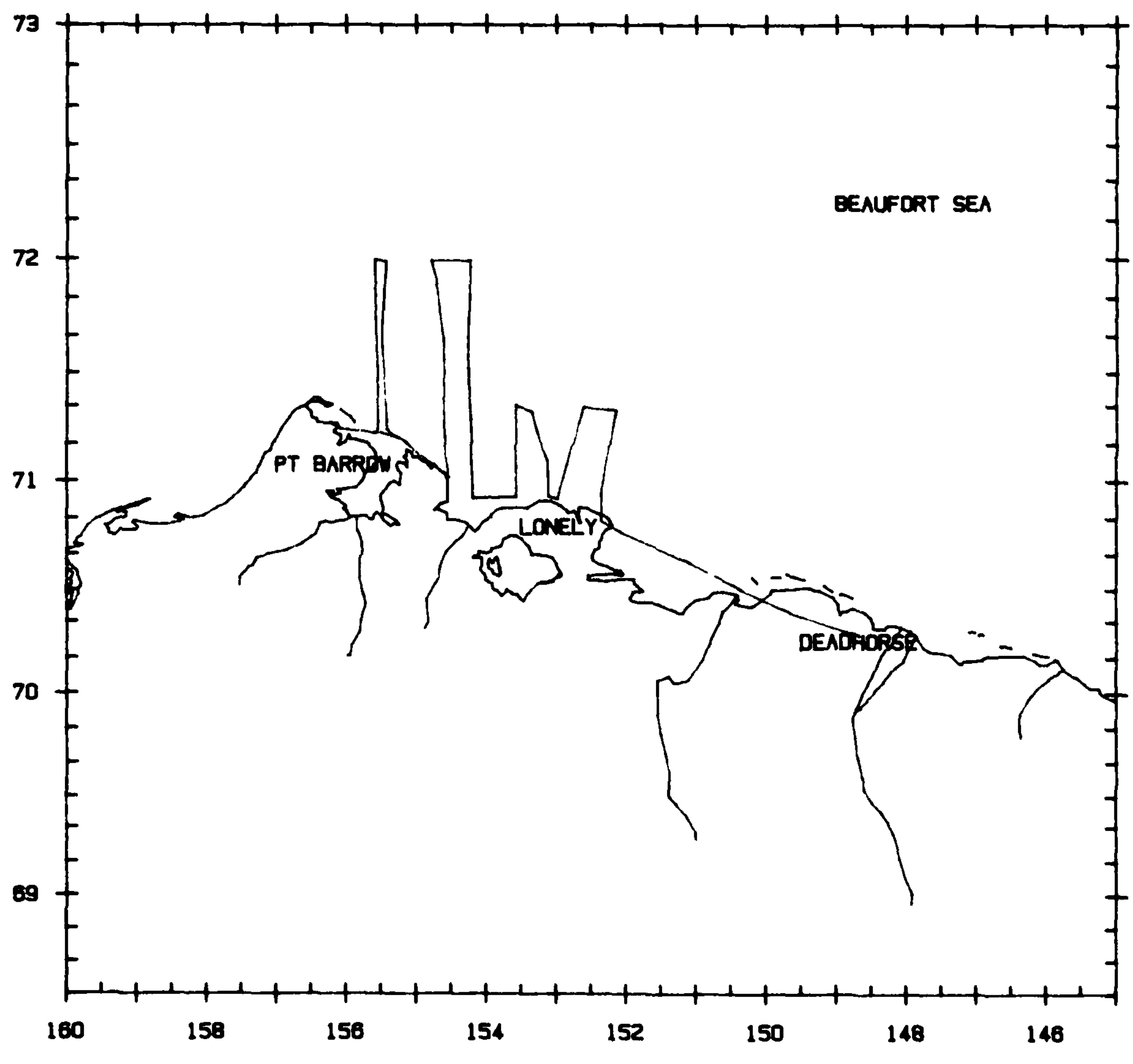
BEAUFORT SEA
DEADHORSE
BARTER IS.
HERSCHEL IS.
LEGEND
BE

Flight 66: 21 October 1985

Flight was a transect survey of the western one-half of block 3 and the eastern two-thirds of block 12. Weather was partly cloudy and visibility was unlimited. Ice coverage was 95 to 99 percent and sea state was Beaufort 00. No marine mammals were seen.



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BEAUFORT SEA
PT BARROW
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DEADHORSE
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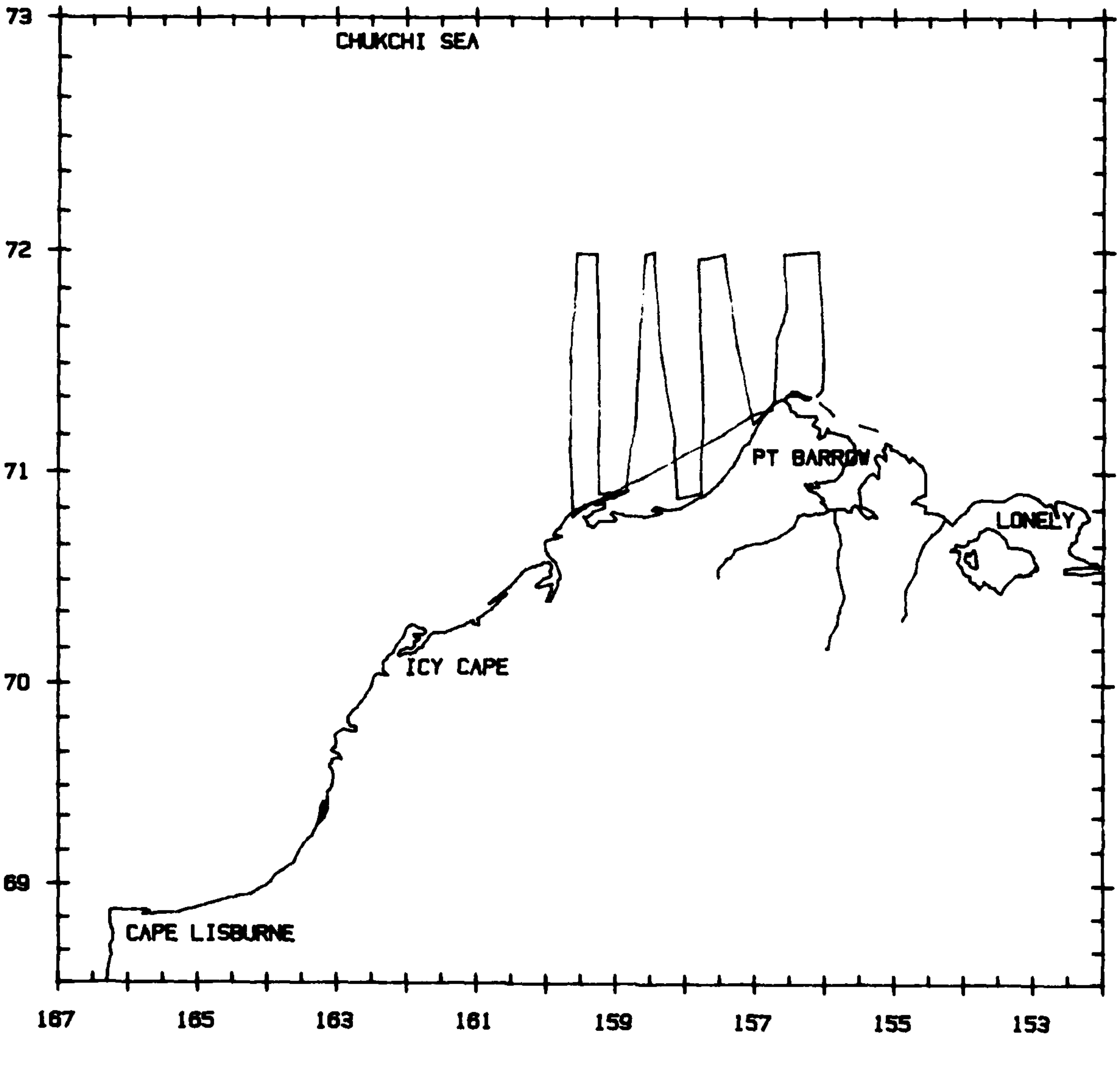
Flight 67: 23 October 1985

Flight was a transect survey of block 13 and the western one-third of block 12. Weather was overcast and visibility was 5 to 10 km. Ice coverage was 99 percent and sea state was Beaufort 00. No marine mammals were seen.



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CHUKCHI SEA
PT BARROW
LONELY
ICY CAPE
CAPE LISBURNE
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APPENDIX B

DISTRIBUTION OF 1985 SURVEY EFFORT AND OBSERVED DENSITIES OF BOWHEAD AND GRAY WHALES IN THE ALASKAN BEAUFORT, EASTERN CHUKCHI AND NORTHERN BERING SEAS, WITH COMPARISONS TO 1979 THROUGH 1984

CONTENTS

FIGURES

TABLES

INTRODUCTION

This appendix presents an analysis of aerial survey data collected during 1985*, and a summary of similarly analyzed data for 1979-84. The objectives of the analysis were to estimate the density of bowhead whales in the Beaufort Sea, and of gray whales in the Chukchi and Bering Seas. Estimating the density of a species provides an evaluation of the relative importance of an area to that group. The density estimate for a particular area is useful when assessing how a portion of a species' range is utilized by the population. Sequential density estimates provide an invaluable tool when determining a population's response to its environment through time.

An important component of this analysis was determining the distribution of survey effort within specific study areas. The Bering and Chukchi Seas were treated as one study area. The Beaufort Sea was treated as a second study area bounded by 141°W to 157°W longitude and 72°N latitude to the coastline. Both study areas were subdivided to more precisely illustrate survey effort and density of animals. Distribution of survey effort and density of gray whales in the Bering and Chukchi Seas were examined during summer (July). Distribution of survey effort and density of bowhead whales in the Beaufort Sea study area were examined during fall (August-October).

METHODS

Density Estimates

Estimating population density requires calculating the portion of that population which is never sighted. In order to correctly estimate density of any population, four underlying assumptions must be adhered to. The assumptions are as follows:

- There are no measurement errors and no rounding errors.
- Sightings are independent events.
- Individuals are fixed at an initial sighting position and no individuals are counted twice.
- A sample of the population is collected at random; no individual is biasedly selected during a count (Cox, 1958; Anderson et al., 1976).

*Density estimates for 1985 survey data were also calculated for survey blocks and provided in the report text (Figures 5 and 11).

Two factors inherent in a study of cetaceans that cause an individual to be missed during a count are sightability and submergence. Sightability means an individual may be at the surface but missed by the observer. As the distance increases between the observer and a whale, the chance of sighting the whale decreases (Doi, 1974, 1975). Transect estimators are designed to work in planar situations. Hence, it is the portion of a population surfaced but not sighted that is calculated when estimating population density. Secondly, whales are not sighted because they are submerged. A distinction must be made between whales at the surface but not sighted, and submerged whales that cannot be sighted. Submerged whales are **never** calculated in the population density estimate. These whales represent a source of known but currently unmeasureable error in the total population estimate (Eberhardt et al., 1979). Additional assumptions peculiar to estimating cetacean density that stem from their sightability and submergence characteristics are:

- Only surfaced animals are counted, and density estimates are calculated only for the population of whales not submerged during an observation period.[1]
- The whales' behaviors do **not** change over the period for which an estimate is calculated (i.e., whales maintain the same swimming speeds and dive patterns throughout the migratory period). This assumption is critical, but difficult to satisfy because whales' behaviors do change over the period of migration.
- Observers are equally effective on both sides of the aircraft and in all areas of the sighting sector. This assumption is necessary since each observer's sightings are weighted equally by formulas used in calculating population size. Any deviation from this assumption will cause a negative or downward bias on the final estimate.

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[1]A combined estimate of the population of surfaced and submerged whales can be calculated if a ratio of dive time to surface time is known. This ratio is a correction factor which permits one to adjust the population estimate to incorporate submerged whales. Presently no good correction factor exists for all behavioral situations. Whales seen during the fall in the Beaufort Sea can either be actively migrating, moving slowly, resting or milling and feeding. Although dive-time ratios have been calculated for milling and feeding whales (see Table 39), these ratios may not be appropriate to use as correction factors for migrating whales.

- Group size does not affect detection of whales. A violation of this assumption would cause a negative bias, since some classes of groups would not be sighted. This assumption is probably violated because larger groups are indeed easier to sight and because the larger the group, the higher the probability of having a whale at the surface.
- Whales do not evade the aircraft. This assumption is probably met because the speed of the aircraft is so much greater than that of the whales (ie., the aircraft probably approaches a whale before the whale can evade it by diving).
- Unity of detection occurs on the flight track. All whales are sighted if they are on the transect line. The only whales that an observer fails to sight are those that are some distance away from the survey aircraft (Burnham et al., 1980).

Strip and Line Transect Methodologies. Strip transect and line transect represent two analytical methodologies used to derive density estimates. The fundamental difference between the two is that a strip transect samples a strip defined by boundaries, while line transect samples an area without boundaries. Both methods sample from a predetermined, randomly selected transect. The basic formula for strip transect estimators (Hayne, 1949) is as follows:

$$N = \frac{nA}{2\,LH} \quad ,$$

where N is the estimated animal population, n is the number of individuals counted, A is area of strip, L is the transect length, and H is the mean sighting distance. Strip transects have a predetermined strip width, within which the observer is required to be certain of counting all individuals. This method does not utilize a detection function that incorporates sightings to the horizon. Individuals outside the strip are not counted, even if seen. For this reason, strip transect methods are recommended when the species density is high and individual counts are large. Line transect estimators are, conceptually, a strip transect with infinite strip width. Line transect methods use the following formula to estimate density:

$$D = \frac{n\,f(o)}{2L} \quad ,$$

where D is the estimated density, n is the number of animals sighted while surveying from a transect, f(o) is the normalized detection function or the probability of sighting and animal, and L is the total transect length surveyed. The number of animals sighted and the transect length surveyed are known parameters. The detection function is the probability of sighting a surfaced whale at a known distance from the transect and must be estimated for density to be calculated. It is used to determine the number of animals on the surface that are not seen. As long as sampling is completed as a series of random transects, the detection function f(o), is the critical estimation made. Determining which specific mathematical model best fits the detection function is most easily done by program computer models. TRANSECT (Burnham et al., 1980) is a program inclusive of parametric and non-parametric mathematical models applicable to fitting curves to data consisting of perpendicular distances.

A critical assumption that must be satisfied to validate the detection function is unity at the transect line; all individuals that occur on the transect line are counted. This assumption was violated because the aircraft's design prevented searching between clinometer angles of 90° and 70° from the horizon. To compensate, all perpendicular distances were adjusted by subtracting a distance from the transect's centerline to a parallel line drawn by the 70° angle specific for the highest altitude flown. The original assumption of unity is modified to assume unity of sightings at these two parallel lines (Figure B-1). The lines are placed at a position equidistant from the transect line, the distance being the perpendicular distance for a 70° clinometer angle at the highest altitude surveyed.

Previous studies have shown that both the accuracy and precision of line transect estimators rely on the ability to determine the exact distance of an individual sighting from the transect line. A fundamental problem now arises. The transect line has been transformed to represent two parallel lines determined by a 70° clinometer angle at the highest altitude surveyed. If a sighting occurs at an altitude lower than the altitude used to attain the parallel transect lines, but at a 70° angle, the sighting will occur in a mathematical "blind spot," the blind spot being the area between the two parallel lines. A blind spot confuses any effort to mathematically model the true probability of detecting whales at varying distances from the survey aircraft. A negative bias or underestimation of the true population is the result of a mathematical blind spot.

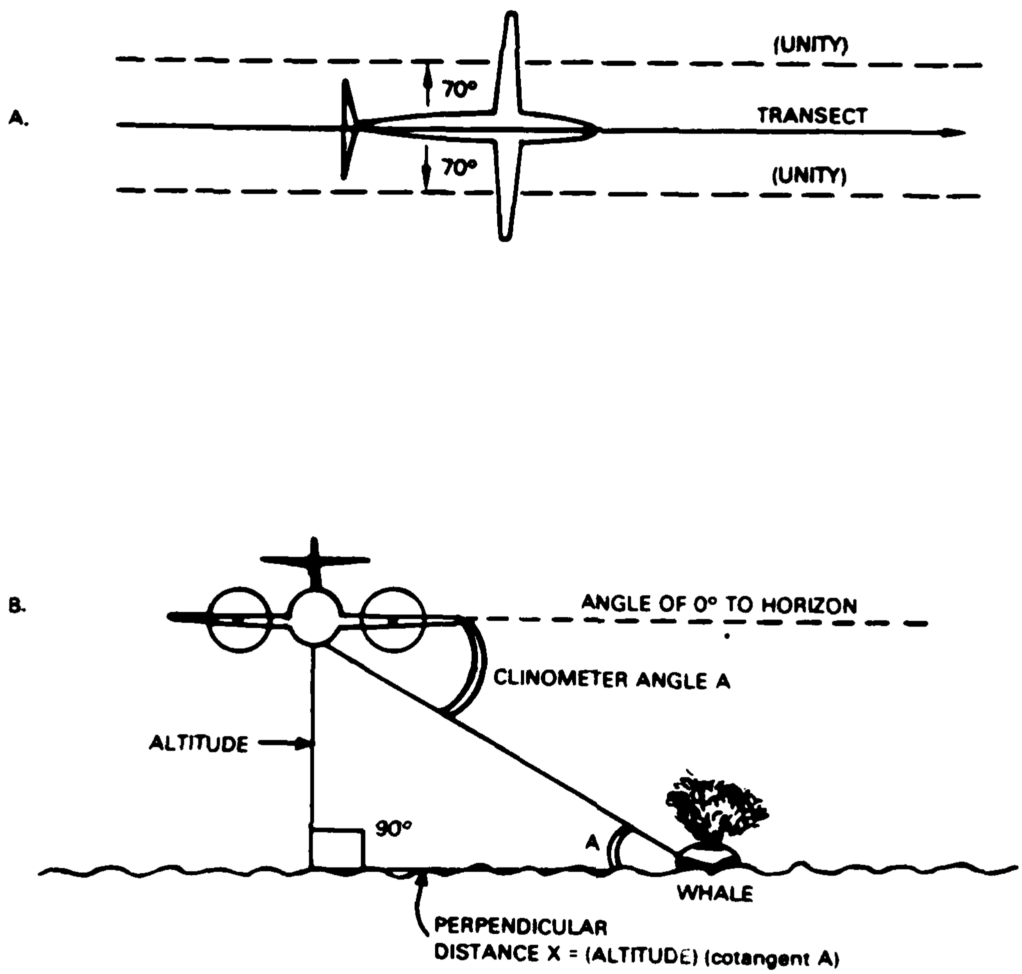

Figure B-1. Due to aircraft design, the assumption of unity at centerline is modified to assume unity at two parallel lines drawn by the 70° angle for the highest altitude flown.

A second method employed by Leatherwood et al. (in press) to compensate for the blind spot beneath the aircraft during line transect analysis, was to replace the parallel-line assumption with a new one that requires all marine mammals to be seen at some fixed perpendicular distance (x_0) from the transect line. The resulting density values experience no aliasing, as introduced by the subtraction method when estimating sightability via the detection function, but nevertheless result in a minimum estimate.

One additional assumption that may be violated is that there are no measurement errors and no rounding errors. Exact sighting angles are difficult to obtain. A deviation of several degrees from the true sighting angle will significantly alter a line transect density estimate.

Map Preparation

Maps were prepared using the computer program AMP, A Mapping Package, consisting of FORTRAN subroutines which can be used for customized plotting applications. AMP was used to plot aerial survey data which resided on file as a series of geographic coordinates (latitude and longitude) associated with time and sightings of whales. Land masses are part of the AMP data base. Depth contours were plotted by reading a separate file of data points prepared for this analysis.

Depth contours were digitized using several reference maps. It was necessary to use more than one map because not all contours were available on any one map. The U.S. Geological Survey Map Open - File 76 - 823, Sheet 1 or 2 was used to digitize the 50 m and greater depth contours, plus all contours shown in the Chukchi Sea except for the 30 m depth contour off the Soviet coastline. The 30 m depth contour off the Soviet coastline and in the Bering Sea was taken from U.S. Department of Commerce map 514, 4th Ed., Apr. 11/81. In the Beaufort Sea, the 10 m, 20 m, and 30 m depth contours were taken from two maps labeled Data from: Geophysical Corp. of Alaska, 1975, NOAA, Department of Commerce Charts, USGS Department of Interior Charts which were additionally labeled as Eastern Beaufort Sea and Western Beaufort Sea.

When the depth contours were merged onto a single data file and plotted, some inconsistencies became apparent. For example, a 30 m depth contour from one map file crossed over the 50 m depth contour from another map file. When this situation occurred, a portion of one of the depth contours was clipped to resolve the inconsistency. Note that portions of the 20 m and 30 m depth contours were clipped near Pt. Barrow, Alaska, and that the 50 m depth contour was clipped near St. Lawrence Island in the Bering Sea.

Data Processing and Quality Control

A computer program was written to screen for bad data values. The chronological order of time was checked. Aerial survey data files were screened for obvious errors in geographic position by separately plotting the course of each daily aerial survey. A computer program was used to calculate flight speeds and distances on a point to point basis, and listings of these values were scanned for suspiciously slow or fast speeds. The listings and maps were compared; errors were flagged and edited and the process was repeated until data files were error-free with respect to these conditions.

Definition of Areas and Methodological Limitations

Survey regions in the Bering and Chukchi Seas were determined based on survey effort and animal distributions (Figures B-2 and B-3). These regions did not conform to survey blocks. The Beaufort Sea study area was divided into four regions from west to east (Figure B-4). Region A extended from 157°00'W to 153°30'W, region B from 153°30'W to 150°00'W, region C from 150°00'W to 146°00'W, and, region D from 146°00'W to 141°00'W.

Depth contours (Figure B-5) were used to stratify the Beaufort Sea from north to south. Depth contours of 10 m, 20 m, 50 m, 200 m, and 200 m were selected (Figure B-6). The stratum from the coastline to 10 m corresponded closely to the area inside the barrier islands (A1, B1, C1, D1A, and D1B) (Figure B-7). Area D1 was divided into D1A and D1B at 143°30' W, which marked the boundary between two areas previously defined for behavioral studies (Figure B-8). The shelf area was stratified from 10 m to 20 m, 20 m to 50 m, and 50 m to 200 m. Areas A2, B2, C2, D2A and D2B corresponded to the 10 m to 20 m strata. Area D2 was divided similarly to D1. Areas A3, B3, C3, and D3 corresponded to the 20 m and 50 m stratum. Areas A4, B4, C4, and D4 corresponded to the 50 m to 200 m stratum. Offshelf strata were defined from 200 m to 2000 m and deeper than 2000 m. Areas A5, B5, C5, and D5 corresponded to the 200 m to 2000 m strata. Areas B6, C6, and D6 corresponded to the deeper than 2000 m strata.

A digitizer was used to trace region boundaries, which led to a boundary problem termed "splinter error." The technique used to digitize each region was to circumscribe it by tracing the boundary of the region. Thus, when two regions were adjacent, the common boundary would be digitized twice. In fact, a boundary was often digitized more than twice. For example, the boundary between regions A1 and B1 was digitized four times because it served not only as a boundary between regions A1 and B1 but also between the larger regions A and B. A splinter error occurred when one set of points defining a common boundary did not exactly match the second, third, or fourth set of points used to define the same boundary for other regions.

Because of this splinter error problem, a very small percentage of the total area may be shared by two regions or may be left out of a region. For example, because of overlap, a small portion of the Beaufort Sea may have been shared during the analysis of two adjacent regions. Conversely, if two sets of points defining a common boundary diverged slightly, a small portion of the Beaufort Sea could have been left out of the analysis.

The implications of the splinter error problem are small in relation to this study. Statistics reported for each subregion, region, and the total study area are valid, but there may be small discrepancies when the values of subregions are summed and compared to the values reported for larger regions, e.g., number of survey hours flown, listed in the tables as Survey Time.

Statistics Presented in Tables

Region Area km^2. Areas were approximated by straight line integration which contributed to discrepancies between the summation of subregion areas and areas calculated for larger regions. Area calculations are accurate to within about 1 percent of the true area.

Percent of Total Area. The percent of total area was calculated as the region area divided by the sum of all subregion areas; this quantity was then multiplied by 100.

Percent of Area Surveyed. The percent of area surveyed is a relative measure of survey effort expended per survey region. Strip width was defined as two kilometers (i.e. one kilometer on either side of the aircraft). Therefore, the total number of kilometers flown equalled half the number of square kilometers surveyed. The percent of total area was calculated as the number of square kilometers surveyed divided by the region area; this quantity was then multiplied by 100.

This technique did not account for overlapping aerial survey strips which result in double counting the area surveyed. Therefore, some areas surveyed may show more than 100 percent coverage.

Survey Time HR:MIN. This is the time in hours and minutes spent surveying an area. Because of splinter errors and rounding errors, the values reported for time spent surveying subregions did not always equal those reported for larger regions.

Percent of Total Time. This is the time in hours and minutes spent surveying a region divided by the sum of survey times reported for each subregion.

Number of Transects Flown. Transects or flight legs were defined as units of survey effort by the aerial survey team. The beginning and ending of transects were further defined by the survey region boundaries. A portion of an aerial survey leg passing over a region was treated as a transect relative to that region. Thus, one transect could be broken into several transects with respect to subregion analyses. For this reason, the sum of the transects based on subregions was greater than the total number of transects reported for the total region.

Number of Bowheads Observed. This indicates the number of bowhead whales observed within one kilometer of either side of the aircraft. Because of splinter errors, small discrepancies may occur between the sum of the number of whales observed in each subregion, versus the number reported for larger regions.

Density as Number per km^2, Variance and Confidence Range. Calculation of density statistics for each stratum followed the method employed by Krogman et al. (1979), which was based on the strip transect technique described in Estes and Gilbert (1978):

$$\hat{R} = \Sigma y_i / \Sigma x_i \quad (1)$$

where $\hat{R}$ = observed density of whales per square kilometer

y_i = number of whales observed in the ith strip transect

x_i = area of the ith strip transect

$$S^2_{\hat{R}} = [\Sigma(y_i^2/x_i) - \hat{R}\Sigma y_i]/(n-1)(\Sigma x_i) \quad (2)$$

where $S^2_{\hat{R}}$ = variance of R

n = number of strip transects

$$\text{C.I.} = \hat{R} \pm t_{.05}(2)V\sqrt{V(\hat{R})} \quad (3)$$

The notation $t_{.05}(2)V$ refers to the critical value of t where alpha (α) - .05 (1- = .95) based on two-tailed test with V degrees of freedom. Degrees of freedom were calculated as the total number of transects minus one.

RESULTS AND DISCUSSION

Results are presented by area, season, and species. Each presentation consists of:

- o Table of statistics associated with each region presenting 1985 data
- o Summary table of statistics associated with each region, 1979-1984

Please refer to the table of contents for order of presentation of results.

BERING AND CHUKCHI SEAS STUDY AREA

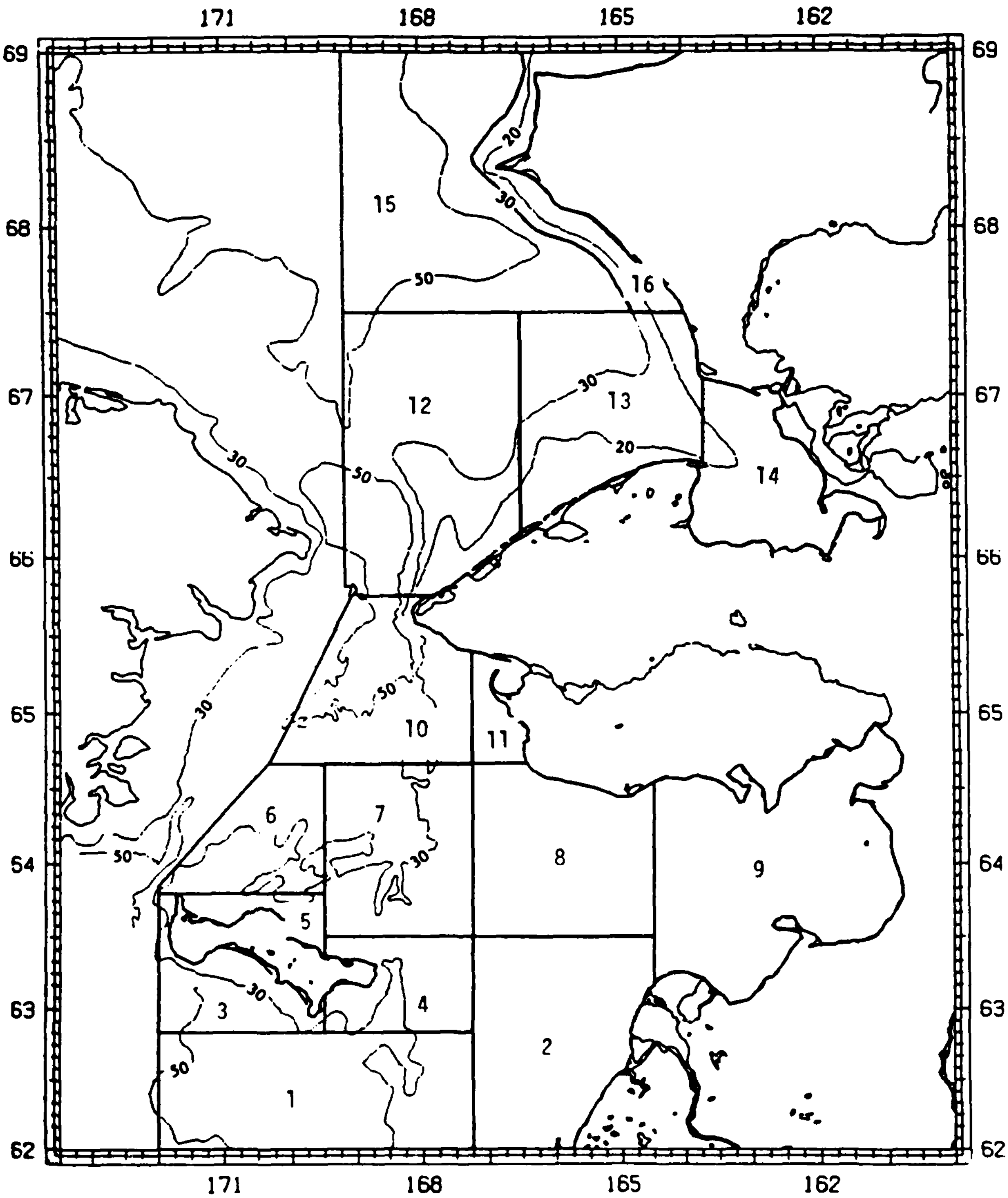

Figure B-2. Map depicting survey regions in relation to depth contours in the Bering and Chukchi Seas.

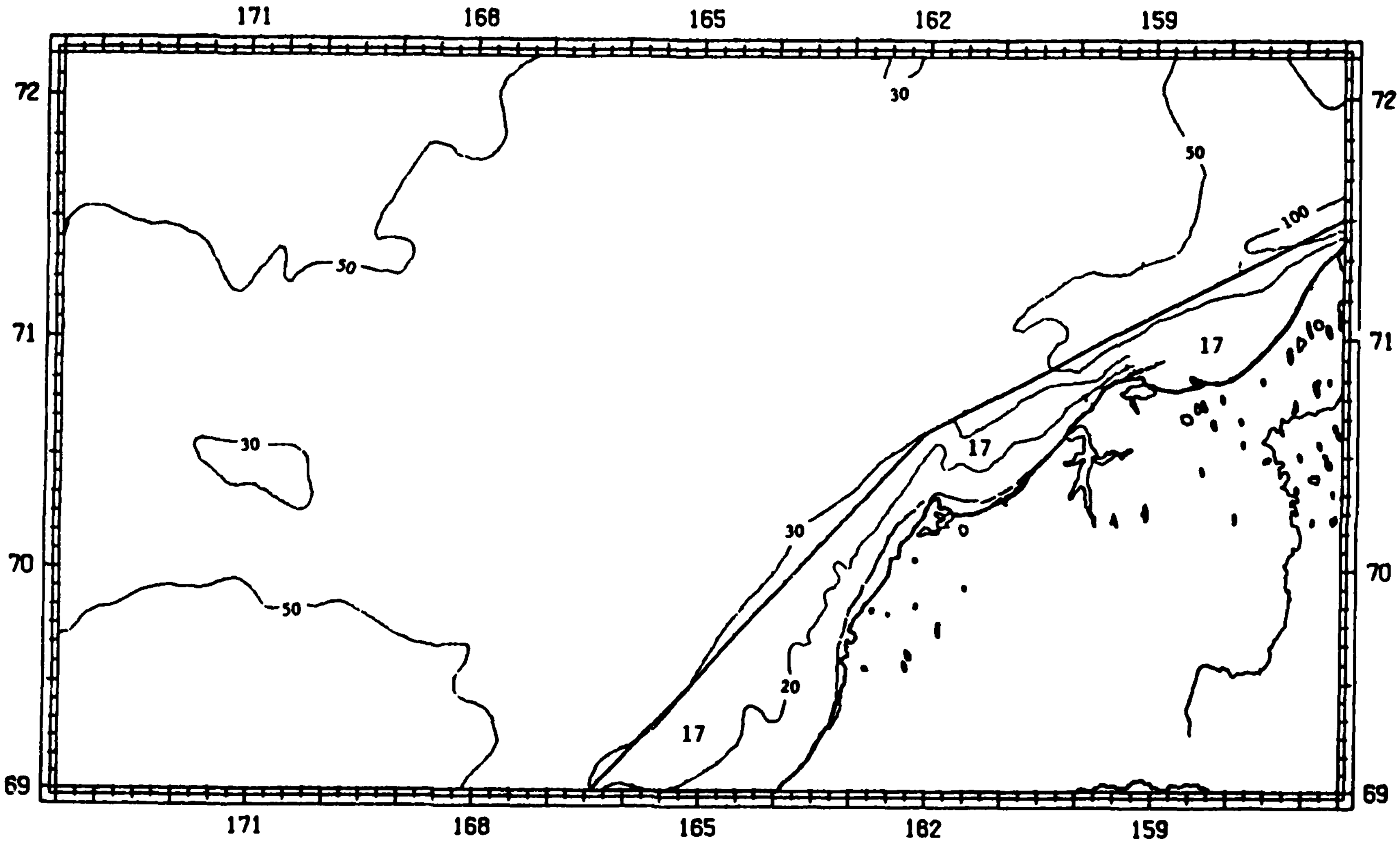

Figure B-3. Map depicting survey region 17 in relation to depth contours in the Chukchi Sea.

Table B-1. Statistics from aerial surveys of gray whales conducted July 1985 in the Bering and Chukchi Seas. Values for each region were summed where appropriate. Region numbers refer to areas depicted in Figures B-2 and B-3.

Region Name	Region Area km^2	Percent of Total Area	Percent of Area Surveyed	Survey Time HR:MIN	Percent of Total Time	Number of Transects Flown	Number of Gray Whales Observed	Density as number per km^2	Variance $(*10^4)$	Confidence Range of Density
1	22,438	10.08	0.0							
2	19,036	8.56	0.0							
3	6,898	3.10	0.0							
4	7,584	3.41	0.0							
5	2,483	1.12	0.0							
6	7,933	3.56	3.62	0:29	5.59	2	0	0	0.0	0.0
7	14,021	6.30	2.06	0:29	5.59	2	45	0.160	70.0	0.00-1.2
8	15,661	7.04	0.0							
9	24,908	11.19	0.0							
10	12,608	5.67	6.70	1:48	20.90	6	71	0.084	11.0	0.00-0.17
11	2,631	1.18	1.64	0:05	0.89	2	0	0.0	0.0	0.0
12	21,214	9.53	0.0							
13	14,200	6.38	0.0							
14	8,468	3.81	0.0							
15	19,780	8.89	5.37	1:51	21.40	7	0	0.0	0.0	0.0
16	5,159	2.32	3.15	0:18	3.54	9	0	0.0	0.0	0.0
17	17,479	7.86	11.61	3:38	42.09	24	8	0.004	0.042	0.00-0.008

Table B-2. Statistics from aerial surveys of gray whales conducted July 1980-1984 in the Bering and Chukchi Seas.

		1980			1981			1982		
Region Name	Region Area km^2	Percent Area Surveyed	Number Grays Observed	Density Number per km^2	Percent Area Surveyed	Number Grays Observed	Density Number per km^2	Percent Area Surveyed	Number Grays Observed	Density Number per km^2
1	22,438	0.0		--	0.0		--	0.11	0	0.0
2	19,036	0.0		--	2.23	0	0.0	0.0		--
3	6,898	0.0		--	0.0		--	1.73	11	1.087
4	7,584	0.0		--	8.20	0	0.0	17.66	40	0.350
5	2,483	0.0		--	0.0		--	22.81	6	0.123
6	7,933	0.0		--	0.0		--	12.18	7	0.086
7	14,021	0.0		--	10.74	46	0.360	30.55	56	0.154
8	15,661	0.22	0	0.0	18.21	0	0.0	6.02	1	0.014
9	24,908	1.39	0	0.0	7.86	0	0.0	0.0		--
10	12,608	1.23	0	0.0	13.65	14	0.096	23.18	37	0.147
11	2,631	3.69	0	0.0	36.54	5	0.062	15.73	0	0.0
12	21,214	1.52	0	0.0	7.09	9	0.072	13.85	5	0.021
13	14,200	0.46	0	0.0	10.23	0	0.0	7.30	1	0.010
14	8,468	0.0		--	8.29	0	0.0	6.05	0	0.0
15	19,780	0.50	0	0.0	4.73	12	0.151	0.0		--
16	5,159	3.51	4	0.261	25.79	28	0.247	7.75	24	0.707
17	17,479	3.74	4	0.072	5.02	21	0.281	3.83	84	1.475

		1983			1984		
Region Name	Region Area km^2	Percent Area Surveyed	Number Grays Observed	Density Number per km^2	Percent Area Surveyed	Number Grays Observed	Density Number per km^2
1	22,438	0.0		--	0.0		
2	19,036	1.71	0	0.0	0.0		
3	6,898	0.0		--	0.0		
4	7,584	9.56	0	0.0	0.0		
5	2,483	0.0		--	0.0		
6	7,933	11.55	65	0.833	0.0		
7	14,021	30.26	429	1.190	3.98	26	0.549
8	15,661	6.76	0	0.0	3.12	0	0.0
9	24,908	2.67	0	0.0	0.0		
10	12,608	19.00	346	1.698	1.32	0	0.0
11	2,631	5.00	0	0.0	6.58	0	0.0
12	21,214	0.62	1	0.089	1.05	0	0.0
13	14,200	2.24	4	0.147	0.88	0	0.0
14	8,468	0.0		--	0.0		
15	19,780	0.46	0	0.0	0.69	3	0.257
16	5,159	3.72	6	0.367	3.45	9	0.593
17	17,479	3.65	0	0.0	13.41	17	0.086

BEAUFORT SEA STUDY AREA

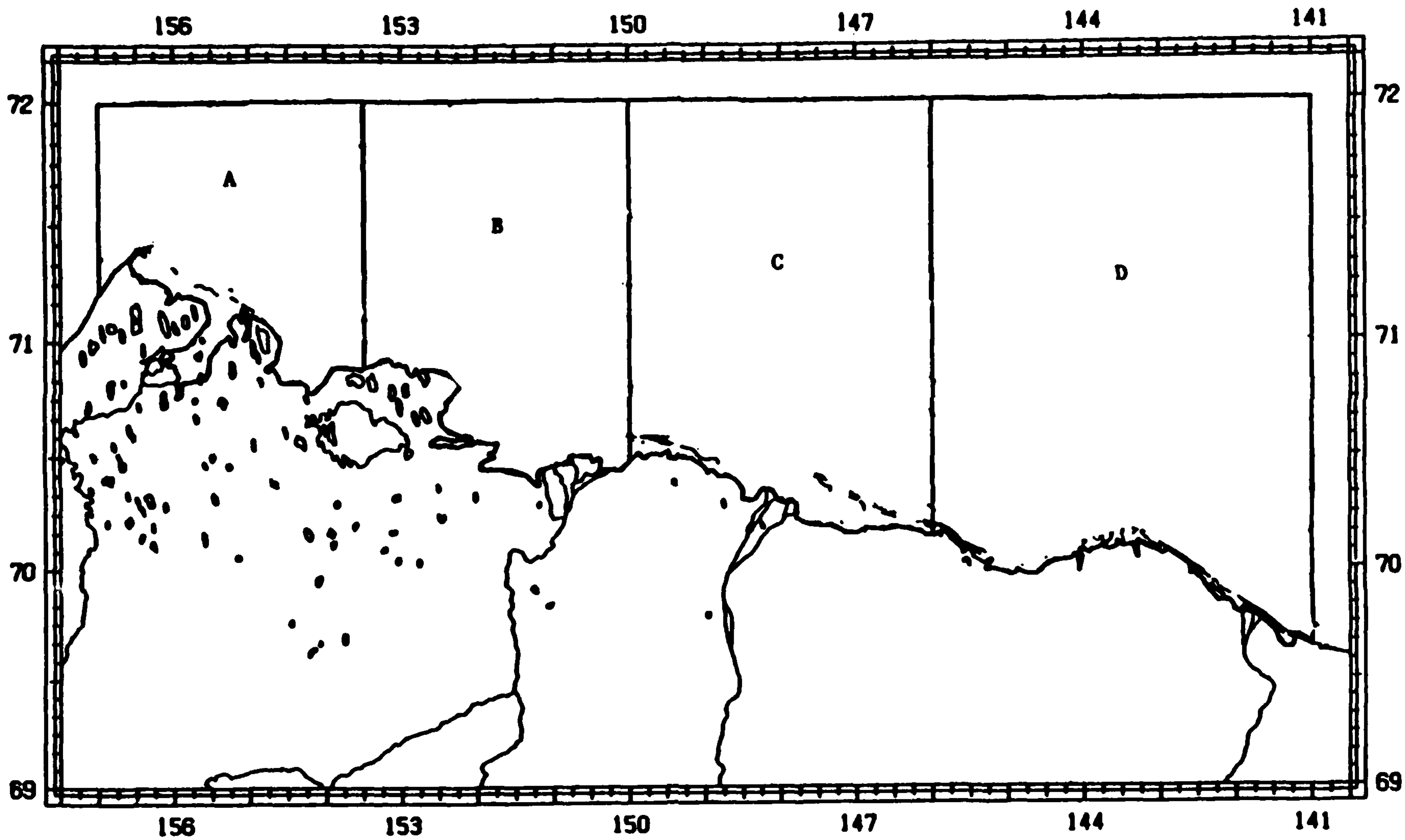

Figure B-4. The Beaufort Sea study area was divided into four regions: A, B, C, and D.

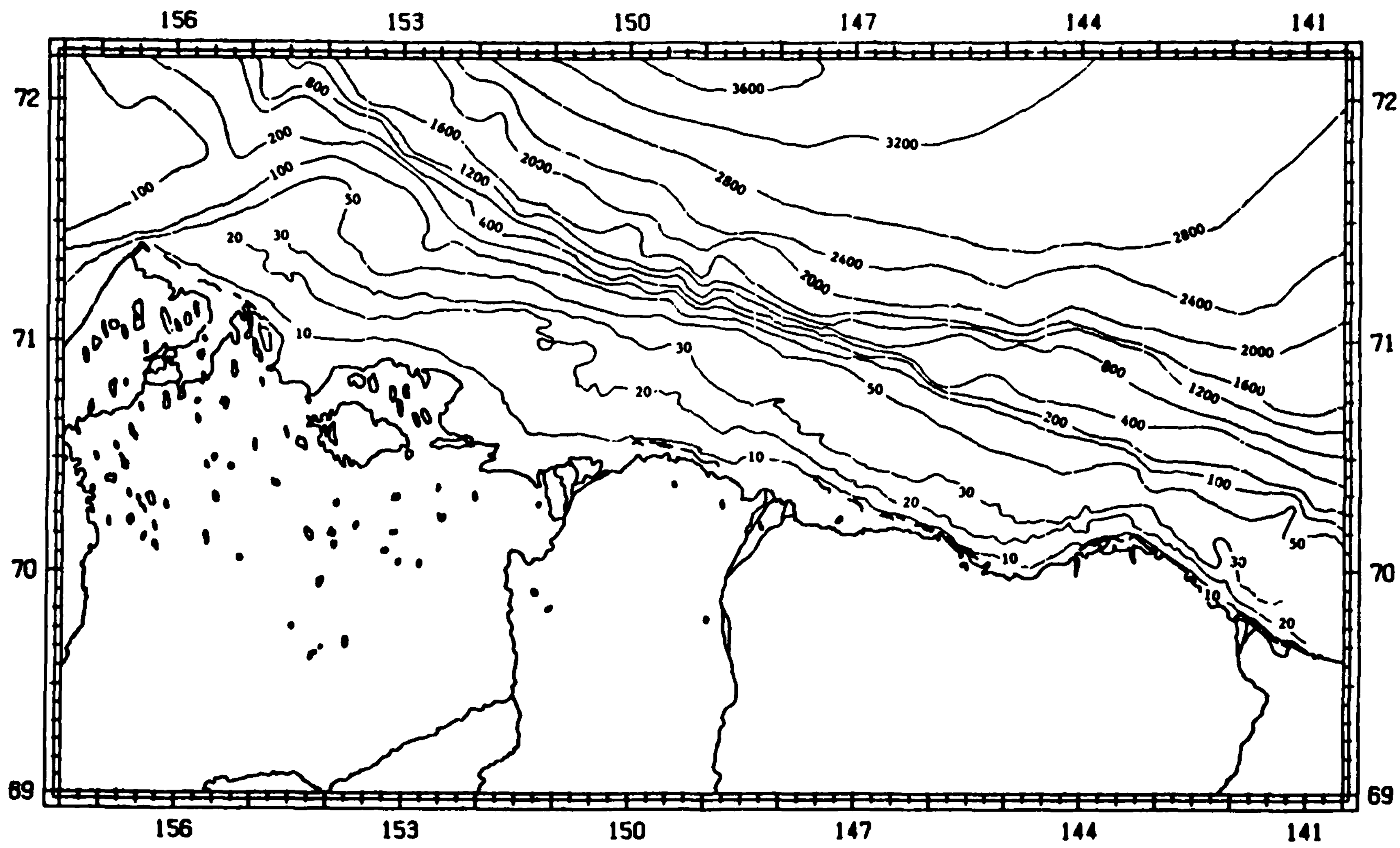

Figure B-5. Beaufort Sea depth contour lines, in meters.

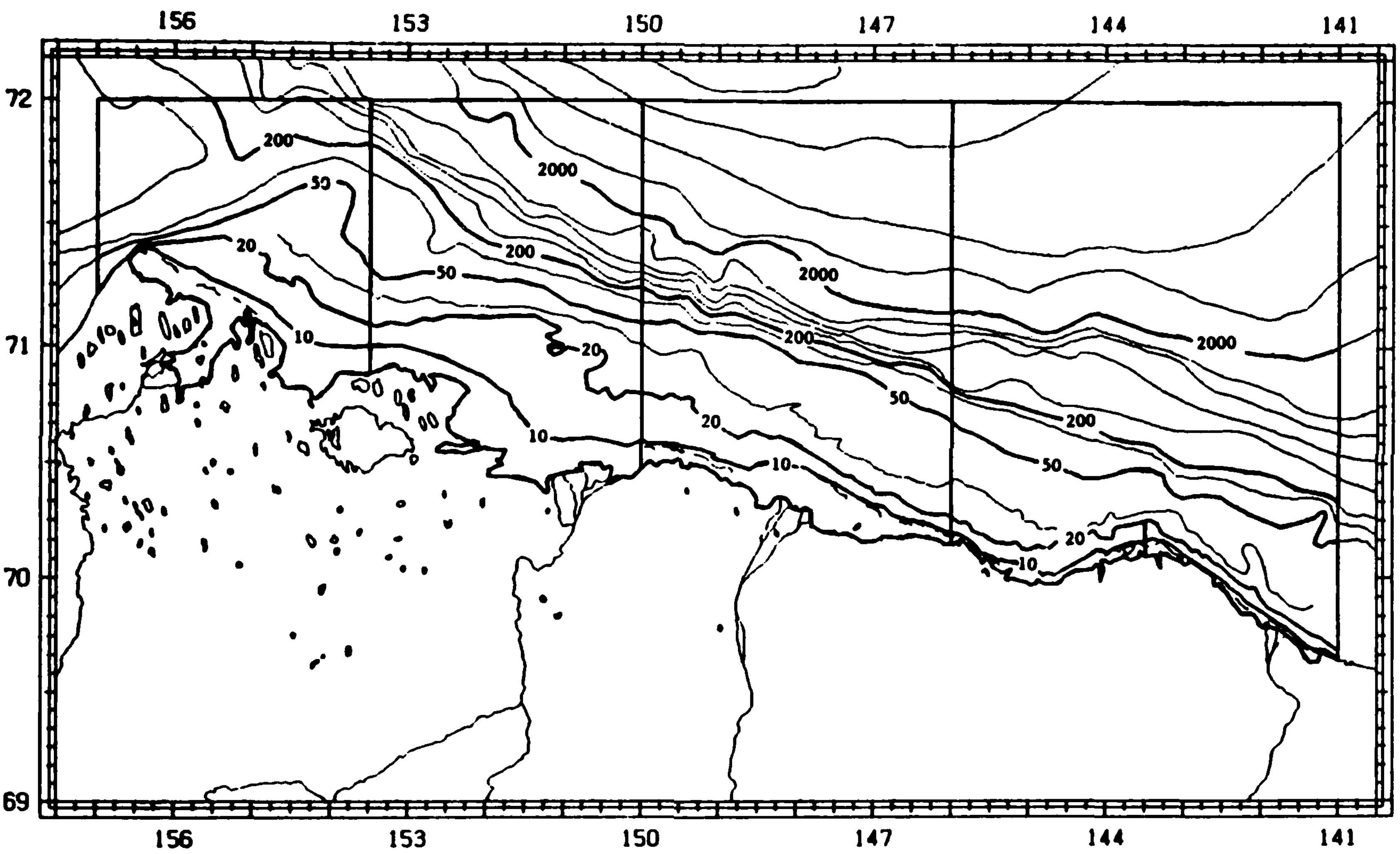

Figure B-6. Map depicting the survey regions in the Beaufort Sea after stratification by contour intervals of 10 m, 20 m, 50 m, 200 m,and 2000 m.

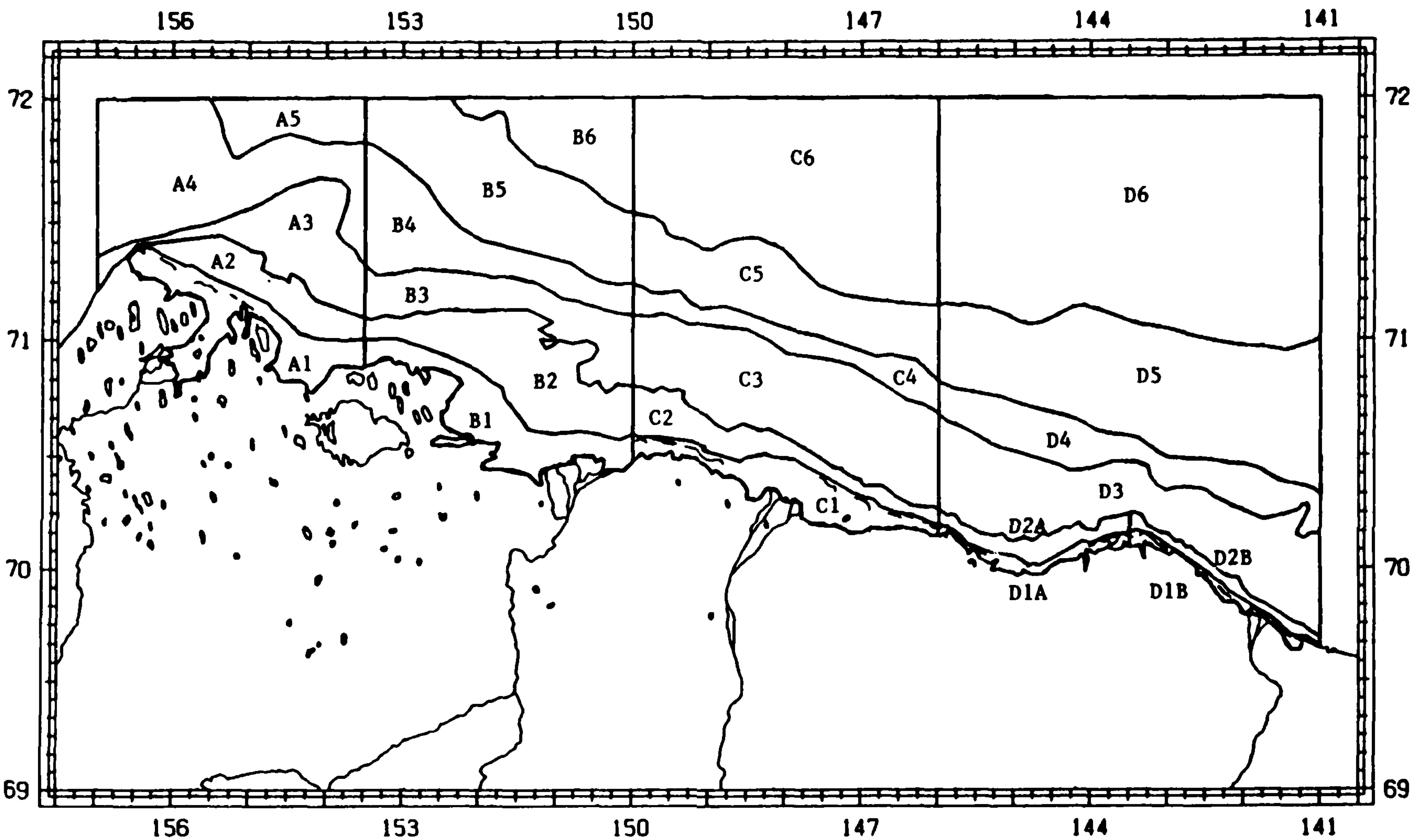

Figure B-7. Map depicting Beaufort Sea stratum names. Strata A1, B1, C1, D1A and D1B extended from the coast out to the 10 meter depth contour. Strata A2, B2, C2, D2A and D2B fell between the 10 and 20 meter depth contours; A3, B3, C3 and D3, fell between the 20 and 50 meter depth contours; etc. Strata D1A, D1B, D2A and D2B are enlarged in Figure B-8.

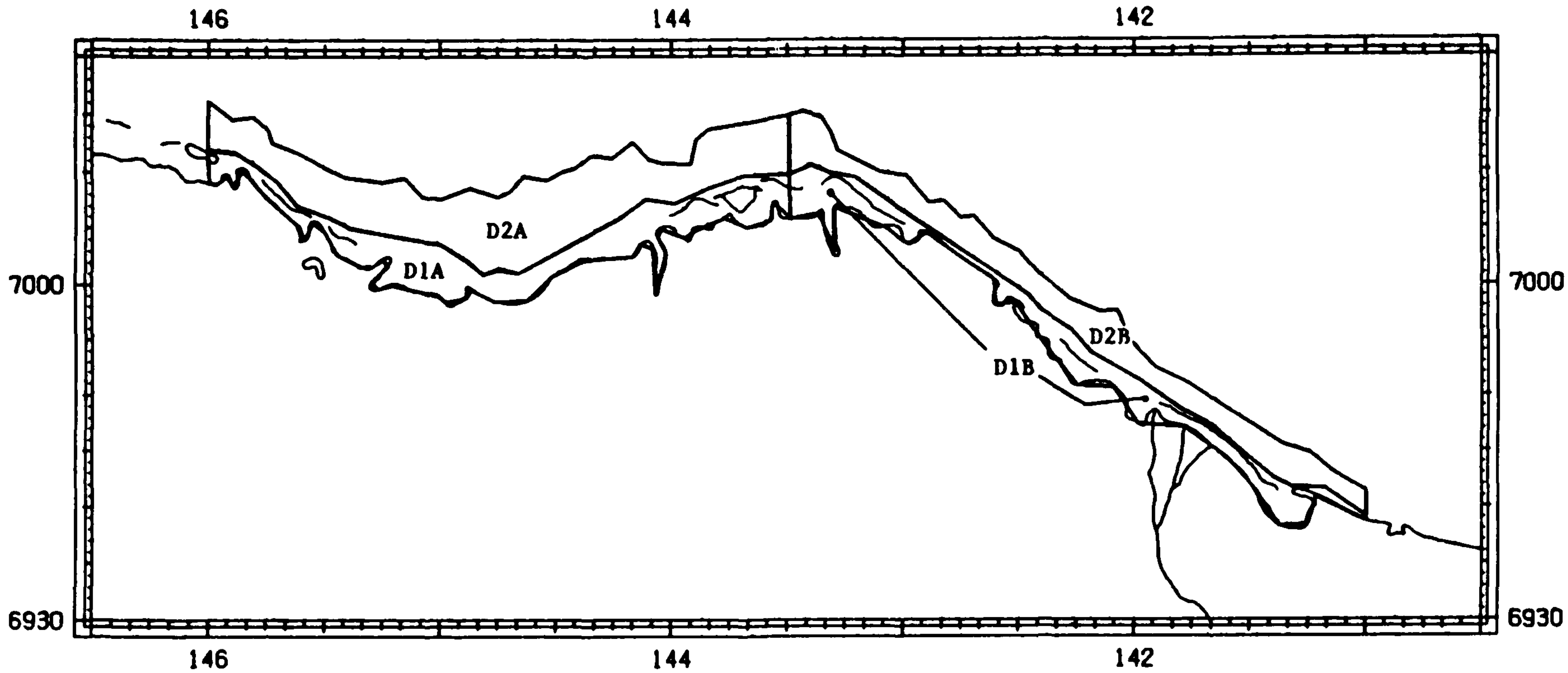

Figure B-8. Map depicting Beaufort Sea strata D1A, D1B, D2A and D2B. Regions D1A and D1B extended from the coast out to the 10 meter depth contour. Regions D2A and D2B extended from the 10 meter to the 20 meter depth contour.

Table B-3. Statistics from aerial surveys of bowhead whales conducted August 1985 in the Beaufort Sea. Values for each region were summed where appropriate. Region numbers refer to areas depicted in Figure B-7.

*The total area of all regions was approximately 101,248 km^2; areas were approximated by straight line integration.

Region Name	Region Area km^2	Percent of Total Area	Percent of Area Surveyed	Survey Time HR:MIN	Percent of Total Time	Number Transects Flown	Number Bowheads Observed	Density as Number per km^2	Variance ($*10^{-4}$)	Confidence Range of Density
Total	*101,248	100.00	11.97	22:37	100.00	298	1	0.0001	0.0001	0.0-0.0003
A										
A1										
A2										
A3										
A4										
A5										
B										
B1										
B2										
B3										
B4										
B5										
B6										
C	27,156	27.	7.85	04:00	17.69	61	0	0	0	0
C1	2,086	2.06	1.61	00:03	0.22	3	0	0	0	0
C2	1,809	1.79	10.52	00:23	1.67	9	0	0	0	0
C3	6,482	6.40	17.35	02:08	9.47	23	0	0	0	0
C4	1,803	1.78	14.49	00:29	2.23	14	0	0	0	0
C5	4,252	4.20	9.53	00:44	3.24	8	0	0	0	0
C6	10,724	10.59	1.08	00:13	0.96	4	0	0	0	0
D	41,139	41.	24.28	18:37	82.31	237	1	0.0001	0.0002	0.0-0.0004
D1A	494	0.49	7.04	00:04	0.32	9	0	0	0	0
D1B	428	0.42	0.70	00:00	0.02	3	0	0	0	0
D2A	915	0.90	40.86	00:44	3.25	23	0	0	0	0
D2B	510	0.50	22.01	00:12	0.91	17	0	0	0	0
D3	6,933	6.85	49.78	06:24	28.27	57	0	0	0	0
D4	3,462	3.42	42.05	02:44	12.07	56	1	0.0007	0.0055	0.0-0.0022
D5	9,785	9.66	34.12	06:12	27.41	43	0	0	0	0
D6	18,612	18.38	6.56	02:17	10.06	29	0	0	0	0

Table B-4. Statistics from aerial surveys of bowhead whales conducted August 1979-1984 in the Beaufort Sea.

		1979			1980			1981		
Region Name	Region Area km^2	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per km^2	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per km^2	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per km^2
Total	101,248	14.43	7	0.007	8.29	0	0.0	6.66	0	0.0
A	13,360	0.0			1.94	0	0.0	5.72	0	0.0
A1	2,361	0.0			3.38	0	0.0	8.20	0	0.0
A2	1,648	0.0			3.37	0	0.0	5.56	0	0.0
A3	2,688	0.0			4.25	0	0.0	9.76	0	0.0
A4	5,166	0.0			0.15	0	0.0	4.00	0	0.0
A5	1,497	0.0			0.0			0.0		
B	19,593	0.0			16.36	0	0.0	7.87	0	0.0
B1	2,614	0.0			36.89	0	0.0	10.96	0	0.0
B2	3,814	0.0			31.23	0	0.0	10.22	0	0.0
B3	2,739	0.0			20.23	0	0.0	19.62	0	0.0
B4	3,061	0.0			12.59	0	0.0	6.71	0	0.0
B5	5,009	0.0			1.90	0	0.0	2.12	0	0.0
B6	2,356	0.0			0.0			0.0		
C	27,156	30.37	0	0.0	12.53	0	0.0	9.09	0	0.0
C1	2,086	134.66	0	0.0	32.67	0	0.0	28.30	0	0.0
C2	1,809	63.95	0	0.0	31.04	0	0.0	41.87	0	0.0
C3	6,482	54.34	0	0.0	29.67	0	0.0	10.12	0	0.0
C4	1,803	8.69	0	0.0	8.49	0	0.0	2.06	0	0.0
C5	4,252	7.83	0	0.0	0.24	0	0.0	2.90	0	0.0
C6	10,724	2.58	0	0.0	0.0			2.44	0	0.0
D	41,139	15.40	7	0.014	3.45	0	0.0	4.71	0	0.0
D1A	494	15.04	0	0.0	11.44	0	0.0	0.0		
D1B	428	0.0			4.93	0	0.0	3.93	0	0.0
D2A	915	111.90	0	0.0	2.85	0	0.0	17.43	0	0.0
D2B	510	9.68	0	0.0	8.11	0	0.0	7.22	0	0.0
D3	6,933	44.65	0	0.0	17.48	0	0.0	21.82	0	0.0
D4	3,462	31.73	4	0.041	0.74	0	0.0	0.0		
D5	9,785	7.05	3	0.051	0.0			1.83	0	0.0
D6	18,612	0.0			0.0			0.0		

		1982			1983			1984		
Region Name	Region Area km^2	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per km^2	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per km^2	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per km^2
Total	101,248	26.94	79	0.034	36.18	10	0.003	29.09	7	0.003
A	13,360	0.0			21.67	0	0.0	6.02	0	0.0
A1	2,361	0.0			24.31	0	0.0	9.99	0	0.0
A2	1,648	0.0			33.17	0	0.0	7.65	0	0.0
A3	2,688	0.0			26.67	0	0.0	9.99	0	0.0
A4	5,166	0.0			16.45	0	0.0	2.39	0	0.0
A5	1,497	0.0			11.23	0	0.0	2.89	0	0.0
B	19,593	0.0			33.21	0	0.0	12.90	0	0.0
B1	2,614	0.0			38.64	0	0.0	15.10	0	0.0
B2	3,814	0.0			65.24	0	0.0	11.17	0	0.0
B3	2,739	0.0			50.90	0	0.0	18.38	0	0.0
B4	3,061	0.0			19.12	0	0.0	10.94	0	0.0
B5	5,009	0.0			12.40	0	0.0	11.84	0	0.0
B6	2,356	0.0			15.55	0	0.0	10.31	0	0.0
C	27,156	17.77	0	0.0	31.52	1	0.0	19.55	0	0.0
C1	2,086	45.68	0	0.0	65.32	0	0.0	75.85	0	0.0
C2	1,809	22.62	0	0.0	53.72	0	0.0	55.73	0	0.0
C3	6,482	24.20	0	0.0	35.07	0	0.0	25.89	0	0.0
C4	1,803	23.77	0	0.0	24.39	0	0.0	15.24	0	0.0
C5	4,252	21.41	0	0.0	20.34	1	0.014	10.29	0	0.0
C6	10,724	4.68	0	0.0	23.48	0	0.0	2.37	0	0.0
D	41,139	54.57	79	0.041	45.28	9	0.007	50.57	7	0.003
D1A	494	140.15	0	0.0	36.62	0	0.0	73.66	0	0.0
D1B	428	57.24	0	0.0	66.13	0	0.0	76.38	0	0.0
D2A	915	109.20	0	0.0	68.66	0	0.0	145.02	0	0.0
D2B	510	123.46	0	0.0	57.30	0	0.0	136.68	2	0.031
D3	6,933	80.48	0	0.0	65.32	2	0.007	93.34	4	[illegible]
D4	3,462	84.05	3	0.014	55.45	0	0.0	67.60	1	[illegible]
D5	9,785	67.16	72	0.130	53.55	3	0.007	48.94	0	0.0
D6	18,612	23.14	4	0.010	28.08	4	0.010	21.85	0	[illegible]

Table B-5. Statistics from aerial surveys of bowhead whales conducted September 1985 in the Beaufort Sea. Values for each region were summed where appropriate. Region numbers refer to areas depicted in Figure B-7.

*The total area of all regions was approximately 101,248 km^2; areas were approximated by straight line integration.

Region Name	Region Area km^2	Percent of Total Area	Percent of Area Surveyed	Survey Time HR:MIN	Percent of Total Time	Number Transects Flown	Number Bowheads Observed	Density as Number per km^2	Variance (*10^{-4})	Confidence Range of Density
Total	*101,248	100.00	14.30	28:58	100.00	326	0	0	0	0
A	13,360	13.	8.68	02:27	8.45	30	0	0	0	0
A1	2,361	2.33	2.61	00:08	0.48	6	0	0	0	0
A2	1,648	1.63	10.71	00:23	1.32	6	0	0	0	0
A3	2,688	2.65	10.31	00:34	1.93	8	0	0	0	0
A4	5,166	5.10	10.05	01:07	3.86	7	0	0	0	0
A5	1,497	1.48	8.31	00:15	0.86	3	0	0	0	0
B	19,593	19.	5.58	02:04	7.12	31	0	0	0	0
B1	2,614	2.58	6.02	00:19	1.09	7	0	0	0	0
B2	3,814	3.77	13.29	01:00	3.44	10	0	0	0	0
B3	2,739	2.71	11.99	00:36	2.07	8	0	0	0	0
B4	3,061	3.02	3.32	00:09	0.52	6	0	0	0	0
B5	5,009	4.95	0.0	00:00	0.00	0	0	0	0	0
B6	2,356	2.33	0.0	00:00	0.00	0	0	0	0	0
C	27,156	27.	15.73	08:38	29.79	109	0	0	0	0
C1	2,086	2.06	9.68	00:25	1.42	14	0	0	0	0
C2	1,809	1.79	28.73	01:05	3.76	24	0	0	0	0
C3	6,482	6.40	30.43	04:10	14.40	24	0	0	0	0
C4	1,803	1.78	24.45	00:52	2.98	19	0	0	0	0
C5	4,252	4.20	21.29	01:42	5.84	19	0	0	0	0
C6	10,724	10.59	2.16	00:24	1.40	9	0	0	0	0
D	41,139	41.	19.34	15:50	54.63	156	0	0	0	0
D1A	494	0.49	4.19	00:03	0.15	6	0	0	0	0
D1B	428	0.42	1.58	00:01	0.05	4	0	0	0	0
D2A	915	0.90	24.99	00:28	1.62	14	0	0	0	0
D2B	510	0.50	22.15	00:13	0.76	13	0	0	0	0
D3	6,933	6.85	30.92	04:17	14.77	31	0	0	0	0
D4	3,462	3.42	25.25	01:48	6.20	28	0	0	0	0
D5	9,785	9.66	24.52	04:47	16.48	32	0	0	0	0
D6	18,612	18.38	11.65	04:14	14.60	28	0	0	0	0

Table B-6. Statistics from aerial surveys of bowhead whales conducted September 1979-1984 in the Beaufort Sea.

		1979			1980			1981		
Region Name	Region Area km2	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per km2	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per km2	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per km2
Total	101,248	18.34	5	0.003	28.10	13	0.007	25.23	158	0.075
A	13,360	1.58	0	0.0	5.83	0	0.0	1.48	0	0.0
A1	2,361	1.86	0	0.0	12.56	0	0.0	0.98	0	0.0
A2	1,648	7.71	0	0.0	15.72	0	0.0	3.02	0	0.0
A3	2,688	1.48	0	0.0	8.12	0	0.0	4.38	0	0.0
A4	5,166	0.0			0.14	0	0.0	0.06	0	0.0
A5	1,497	0.0			0.0			0.0		
B	19,593	1.28	0	0.0	27.61	0	0.0	12.49	0	0.0
B1	2,614	0.0			47.16	0	0.0	5.26	0	0.0
B2	3,814	5.28	0	0.0	51.75	0	0.0	27.66	0	0.0
B3	2,739	1.80	0	0.0	40.71	0	0.0	27.82	0	0.0
B4	3,061	0.0			28.35	0	0.0	13.00	0	0.0
B5	5,009	0.0			4.03	0	0.0	1.41	0	0.0
B6	2,356	0.0			0.0			0.0		
C	27,156	38.33	2	0.003	58.23	6	0.003	36.14	5	0.007
C1	2,086	139.42	0	0.0	190.54	1	0.003	112.97	0	0.0
C2	1,809	78.13	0	0.0	154.06	1	0.003	148.46	0	0.0
C3	6,482	72.99	2	0.003	111.24	3	0.003	66.92	5	0.014
C4	1,803	22.13	0	0.0	30.81	0	0.0	11.13	0	0.0
C5	4,252	14.47	0	0.0	12.39	0	0.0	0.37	0	0.0
C6	10,724	1.45	0	0.0	4.72	0	0.0	0.0		
D	41,139	19.95	3	0.003	15.42	7	0.014	31.59	153	0.144
D1A	494	39.70	0	0.0	65.06	1	0.034	75.12	0	0.0
D1B	428	24.07	0	0.0	83.16	0	0.0	71.77	0	0.0
D2A	915	140.52	1	0.010	96.88	0	0.0	121.26	0	0.0
D2B	510	47.99	0	0.0	78.36	3	0.086	152.46	5	0.072
D3	6,933	52.93	1	0.003	45.30	2	0.007	114.76	145	0.216
D4	3,462	44.12	0	0.0	5.93	0	0.0	9.21	1	0.038
D5	9,785	10.41	1	0.010	5.55	0	0.0	11.81	0	0.0
D6	18,612	0.0			1.78	0	0.0	3.99	0	0.0

		1982			1983			1984		
Region Name	Region Area km2	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per km2	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per km2	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per km2
Total	101,248	29.30	120	0.048	46.69	65	0.017	33.62	182	0.065
A	13,360	20.81	3	0.014	45.24	14	0.027	23.01	135	0.532
A1	2,361	23.84	0	0.0	40.06	0	0.0	10.38	0	0.0
A2	1,648	33.30	1	0.021	63.68	0	0.0	31.34	40	0.912
A3	2,688	31.85	0	0.0	48.72	11	0.099	40.96	57	0.604
A4	5,166	13.44	2	0.034	38.54	3	0.017	17.96	38	0.477
A5	1,497	4.43	0	0.0	47.32	0	0.0	15.69	0	0.0
B	19,593	43.90	7	0.010	58.66	21	0.021	35.23	0	0.0
B1	2,614	52.93	0	0.0	47.34	0	0.0	31.99	0	0.0
B2	3,814	68.27	4	0.017	51.78	0	0.0	54.11	0	0.0
B3	2,739	63.41	2	0.014	59.92	9	0.065	51.18	0	0.0
B4	3,061	46.94	1	0.007	71.80	8	0.041	39.36	0	0.0
B5	5,009	22.95	0	0.0	60.22	3	0.010	21.29	0	0.0
B6	2,356	8.49	0	0.0	53.34	1	0.010	10.28	0	0.0
C	27,156	19.01	58	1.372	64.33	10	0.007	44.76	11	0.010
C1	2,086	60.77	0	0.0	97.34	0	0.0	78.57	0	0.0
C2	1,809	46.59	1	0.014	61.87	0	0.0	71.20	0	0.0
C3	6,482	37.58	56	0.268	79.74	2	0.003	72.15	8	0.021
C4	1,803	20.85	1	0.034	75.25	2	0.017	44.14	3	0.048
C5	4,252	6.54	0	0.0	65.45	4	0.017	27.30	0	0.0
C6	10,724	0.46	0	0.0	44.52	2	0.003	22.21	0	0.0
D	41,139	30.97	52	0.048	29.59	20	0.021	28.76	36	0.038
D1A	494	38.50	0	0.0	17.02	0	0.0	31.34	0	0.0
D1B	428	65.79	0	0.0	3.49	0	0.0	27.20	2	0.206
D2A	915	46.16	0	0.0	17.16	0	0.0	42.15	1	0.031
D2B	510	101.45	0	0.0	17.80	0	0.0	75.49	0	0.0
D3	6,933	59.77	48	0.137	32.40	0	0.0	51.64	14	0.048
D4	3,462	46.39	0	0.0	55.91	2	0.010	39.61	12	0.103
D5	9,785	23.64	0	0.0	46.24	17	[illegible]	27.76	7	0.031
D6	18,612	13.55	4	0.021	14.92	1	0.003	15.49	0	0.0

Table B-7. Statistics from aerial surveys of bowhead whales conducted October 1985 in the Beaufort Sea. Values for each region were summed where appropriate. Region numbers refer to areas depicted in Figure B-7.

*The total area of all regions was approximately 101,248 km^2; areas were approximated by straight line integration.

Region Name	Region Area km^2	Percent of Total Area	Percent of Area Surveyed	Survey Time HR:MIN	Percent of Total Time	Number Transects Flown	Number Bowheads Observed	Density as Number per km^2	Variance (*10^{-4})	Confidence Range of Density
Total	*101,248	100.00	14.58	30:04	100.00	370	10	0.0007	0.0020	0.0-0.0016
A	13,360	13.	32.69	09:17	30.90	104	4	0.0009	0.0012	0.0-0.016
A1	2,361	2.33	10.82	00:32	1.80	20	0	0	0	0
A2	1,648	1.63	44.10	01:34	5.19	21	1	0.0014	0.0145	0.0-0.039
A3	2,688	2.65	41.84	02:22	7.87	26	0	0	0	0
A4	5,166	5.10	35.64	03:56	13.09	25	3	0.0016	0.0069	0.0-0.003
A5	1,497	1.48	28.01	00:53	2.96	12	0	0	0	0
B	19,593	19.	19.10	07:18	24.29	110	4	0.0011	0.0252	0.0-0.0042
B1	2,614	2.58	18.90	01:01	3.36	22	0	0	0	0
B2	3,814	3.77	38.95	02:48	9.31	31	0	0	0	0
B3	2,739	2.71	39.01	01:57	6.51	30	1	0.0009	0.0075	0.0-0.0027
B4	3,061	3.02	15.36	00:55	3.06	18	0	0	0	0
B5	5,009	4.95	4.47	00:37	2.05	9	3	0.0134	5.4100	0.0-0.0670
B6	2,356	2.33	0.0	00:00	0	0	0	0	0	0
C	27,156	27.	8.96	05:00	16.61	56	2	0.0008	0.0020	0.0-0.0017
C1	2,086	2.06	5.17	00:13	0.71	7	0	0	0	0
C2	1,809	1.79	17.30	00:38	2.12	14	0	0	0	0
C3	6,482	6.40	21.93	02:56	9.77	17	2	0.0014	0.0112	0.0-0.0037
C4	1,803	1.78	10.22	00:22	1.24	9	0	0	0	0
C5	4,252	4.20	7.94	00:42	2.32	7	0	0	0	0
C6	10,724	10.59	0.64	00:08	0.44	2	0	0	0	0
D	41,139	41.	10.26	08:29	28.21	100	0	0	0	0
D1A	494	0.49	1.50	00:01	0.05	1	0	0	0	0
D1B	428	0.42	5.37	00:03	0.17	3	0	0	0	0
D2A	915	0.90	17.06	00:19	1.03	8	0	0	0	0
D2B	510	0.50	13.13	00:09	0.50	8	0	0	0	0
D3	6,933	6.85	25.82	03:37	12.05	27	0	0	0	0
D4	3,462	3.42	21.93	01:29	4.93	25	0	0	0	0
D5	9,785	9.66	12.11	02:22	7.87	18	0	0	0	0
D6	18,612	18.38	1.24	00:29	1.60	9	0	0	0	0

Table B-8. Statistics from aerial surveys of bowhead whales conducted October 1979-1984 in the Beaufort Sea.

		1979			1980			1981		
Region Name	Region Area km^2	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per km^2	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per km^2	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per km^2
Total	101,284	24.02	145	0.072	22.24	8	0.003	17.70	46	0.031
A	13,360	19.33	5	0.024	14.06	0	0.0	4.92	0	0.0
A1	2,361	6.59	0	0.0	13.12	0	0.0	12.34	0	0.0
A2	1,648	18.86	0	0.0	18.75	0	0.0	11.74	0	0.0
A3	2,688	26.99	1	0.017	32.01	0	0.0	6.39	0	0.0
A4	5,166	22.71	4	0.041	7.15	0	0.0	0.0		
A5	1.497	10.68	0	0.0	0.0			0.0		
B	19,593	11.84	41	0.213	44.80	4	0.007	30.14	8	0.017
B1	2,614	0.64	0	0.0	74.43	0	0.0	34.01	0	0.0
B2	3,814	23.54	0	0.0	81.18	0	0.0	65.23	0	0.0
B3	2,739	30.52	41	0.580	75.15	4	0.024	59.32	8	0.058
B4	3,061	10.51	0	0.0	41.84	0	0.0	21.86	0	0.0
B5	5,009	4.45	0	0.0	8.55	0	0.0	3.85	0	0.0
B6	2,356	0.0			0.0			0.0		
C	27,156	62.93	81	0.058	34.38	4	0.007	24.84	16	0.027
C1	2,086	258.45	0	0.0	94.01	0	0.0	50.89	0	0.0
C2	1,809	139.58	6	0.027	79.70	0	0.0	67.71	1	0.010
C3	6.482	119.69	75	0.113	77.48	4	0.010	58.35	14	0.045
C4	1,803	23.31	0	0.0	22.51	0	0.0	28.93	1	0.024
C5	4,252	19.97	0	0.0	5.54	0	0.0	0.53	0	0.0
C6	10,724	2.52	0	0.0	0.76	0	0.0	0.0		
D	41,139	5.65	18	0.093	5.92	0	0.0	11.16	22	0.058
D1A	494	3.98	0	0.0	4.96	0	0.0	6.26	0	0.0
D1B	428	0.0			0.0			35.17	0	0.0
D2A	915	46.27	0	0.0	32.94	0	0.0	36.71	0	0.0
D2B	510	0.0			42.15	0	0.0	36.65	0	0.0
D3	6,933	16.11	18	0.192	26.12	0	0.0	31.99	22	0.117
D4	3,462	8.54	0	0.0	0.81	0	0.0	13.09	0	0.0
D5	9,785	1.03	0	0.0	0.0			10.61	0	0.0
D6	18,612	0.02	0	0.0	0.0			0.28	0	0.0

		1982			1983			1984		
Region Name	Region Area km^2	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per km^2	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per km^2	Percent of Area Surveyed	Number Bowheads Observed	Density as Number per km^2
Total	101,248	14.91	25	0.021	18.87	12	0.007	28.80	68	0.027
A	13,360	32.04	11	0.031	43.78	8	0.017	58.36	27	0.041
A1	2,361	15.23	4	0.137	20.67	0	0.0	26.86	0	0.0
A2	1,648	39.58	4	0.072	50.24	0	0.0	78.31	5	0.045
A3	2,688	37.33	1	0.010	43.77	6	0.058	69.45	10	0.062
A4	5,166	34.40	2	0.014	51.15	2	0.010	57.71	12	0.048
A5	1,497	28.09	0	0.0	42.49	0	0.0	62.63	0	0.0
B	19,593	18.17	10	0.034	26.47	3	0.007	51.83	36	0.041
B1	2,614	7.02	0	0.0	17.69	0	0.0	52.89	0	0.0
B2	3,814	12.39	2	0.051	28.83	0	0.0	81.61	1	0.003
B3	2,739	12.57	7	0.240	24.67	3	0.051	90.79	11	0.051
B4	3,061	24.41	0	0.0	33.69	0	0.0	58.62	24	0.158
B5	5,009	22.84	1	0.010	24.32	0	0.0	23.13	0	0.0
B6	2,356	27.23	0	0.0	26.96	0	0.0	4.54	0	0.0
C	27,156	12.18	1	0.003	14.26	0	0.0	29.75	4	0.007
C1	2,086	25.16	0	0.0	29.11	0	0.0	59.39	0	0.0
C2	1,809	26.33	0	0.0	34.31	0	0.0	69.15	0	0.0
C3	6,482	25.82	1	0.007	22.05	0	0.0	54.70	2	0.007
C4	1,803	9.08	0	0.0	14.81	0	0.0	39.11	2	0.038
C5	4,252	6.07	0	0.0	10.68	0	0.0	23.05	0	0.0
C6	10,724	1.18	0	0.0	4.01	0	0.0	2.00	0	0.0
D	41,139	9.52	3	0.010	10.19	1	0.003	6.99	1	0.003
D1A	494	14.81	0	0.0	24.19	0	0.0	5.38	0	0.0
D1B	428	9.20	0	0.0	8.37	0	0.0	3.30	0	0.0
D2A	915	28.50	0	0.0	23.29	0	0.0	14.57	0	0.0
D2B	510	15.55	0	0.0	17.01	0	0.0	40.54	0	0.0
D3	6,933	27.87	3	0.017	20.96	1	0.007	20.36	1	0.007
D4	3,462	13.89	0	0.0	20.04	0	0.0	14.46	0	0.0
D5	9,785	4.14	0	0.0	13.45	0	0.0	5.17	0	0.0
D6	18,612	3.01	0	0.0	0.93	0	0.0	0.00	0	0.0

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APPENDIX C

ASSESSMENT OF BOWHEAD WHALE MIGRATION STATUS, SEPTEMBER 1985

CONTENTS

FIGURES

TABLES

INTRODUCTION

In fall 1985, a secondary aircraft (N545N) was provided by MMS to monitor the location and migration status of bowhead whales in the eastern Alaskan Beaufort Sea. Information on the timing of bowhead movements through the Alaskan Beaufort Sea has become a key element to decision making processes of government official regulating offshore drilling and exploration. Additional tasks of the research team aboard the secondary aircraft included describing the general behavior and sound production of any whales observed. Daily reports of survey effort, survey conditions, and sighting summaries from the secondary aircraft were integrated with reports from the primary aircraft and provided to government officials responsible for regulating offshore drilling and geophysical exploration.

METHODS

The study area and aerial survey procedures utilized by the secondary aircraft were essentially the same as those described for the primary aircraft (see Methods and Materials, p. 3). In general, surveys were concentrated in the southeastern survey blocks (i.e. blocks 4 and 5) in order to intercept the bowhead migration. The survey aircraft was a de-Havilland Series 300 High-Wing Twin Otter (N545N), capable of 9 hours of continuous flight. The aircraft was equipped with bubble windows to enhance viewing, a radar altimeter, and a Global Navigation System (GNS) 500A Series that provided continuous position updates (0.6 km/survey hour, precision). The aircraft and crew of five (pilot, co-pilot, data recorder and two observers) were based at Deadhorse, Alaska, from 7 to 27 September 1985. Data collection and analysis were identical to those techniques used on board the primary survey aircraft (see Methods and Materials, pp. 5-7).

RESULTS

Survey Effort and Sighting Summary

Forty two and three-quarter hours of surveys were flown by the secondary aircraft between 9 and 27 September, with all of the effort taking place in the eastern Alaskan Beaufort Sea (Table C-1, Figure C-1). The majority (97%) of flights were search surveys to assess the bowhead migration status. Bowheads were seen predominantly east of Demarcation Bay near Komakuk Beach, between longitude 140° W and 142° W, and offshore to latitude 70° 06'N. One group of bowheads was seen north of Barter Island in late September (Flight C-11).

Table C-1. Summary of N545N flight effort, fall 1985.

Flight	Date	Transect Length (km)	Search Length (km)	Connect Length (km)	Total Length (km)	Time on Transect (hr:min)	Total Time (hr:min)	WPUE (whales/hr)
C-1	9 Sept	0	116	0	116	0:00	0:50	0.00
C-2	11 Sept	0	665	0	665	0:00	4:04	4.44
C-3	12 Sept	0	720	0	720	0:00	4:41	5.34
C-4	13 Sept	0	707	0	707	0:00	4:31	2.21
C-5	18 Sept	0	675	0	675	0:00	3:55	0.00
C-6	19 Sept	249	636	36	921	1:29	4:50	0.21
C-7	22 Sept	0	922	0	922	0:00	5:51	2.74
C-8	23 Sept	0	770	0	770	0:00	4:01	1.99
C-9	24 Sept	0	727	0	727	0:00	3:37	2.76
C-10	25 Sept	0	530	0	530	0:00	3:10	0.63
C-11	27 Sept	0	604	0	604	0:00	3:20	4.80
Total		249	7072	36	7357	1:29	42:50	2.47

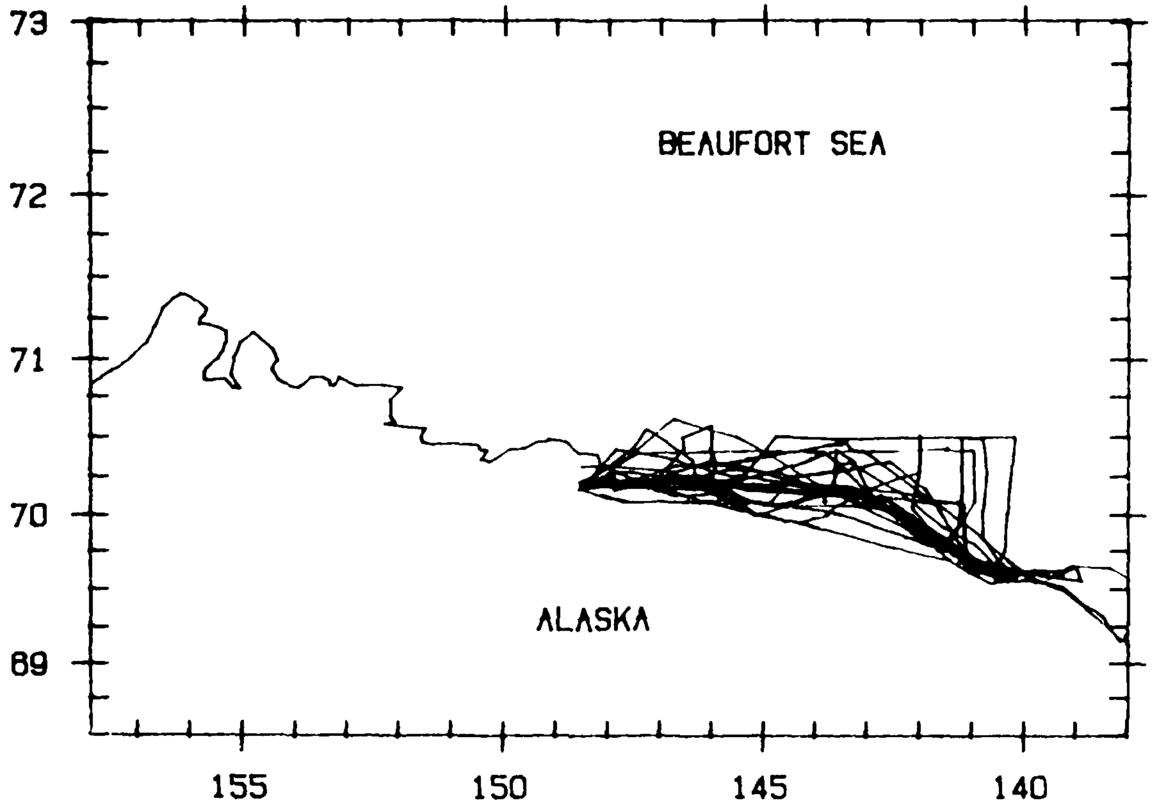


Figure C-1. Composite flight track from 11 flights, N545N, September 1985.

Survey Conditions Summary

Survey conditions throughout September were generally good. Fog and other inclement weather were encountered less often by the secondary aircraft than by the primary survey aircraft since most surveys were flown close to shore over predominantly open water areas. Unacceptable weather conditions curtailed flying on ten days. Ice conditions encountered by the secondary aircraft were similar to those reported for the same time period by the primary aircraft (See Survey Conditions Summary, page 25).

Table C-2. Summary of N545N sightings (number of sightings/number of animals), fall 1985.

Flight	Date	Bowhead	Belukha	Polar Bear
C-1	9 Sept	0/0	0/0	0/0
C-2	11 Sept	1/18	0/0	0/0
C-3	12 Sept	1/25	0/0	0/0
C-4	13 Sept	1/10	0/0	0/0
C-5	18 Sept	0/0	0/0	0/0
C-6	19 Sept	1/1	1/1	0/0
C-7	22 Sept	2/16	3/15	1/1
C-8	23 Sept	1/8	2/41	0/0
C-9	24 Sept	5/10	0/0	1/4
C-10	25 Sept	2/2	0/0	0/0
C-11	27 Sept	5/16	1/7	0/0
		19/106	7/64	2/5

Bowhead Whale

Distribution and Relative Abundance

Nineteen sightings of 106 bowheads were made by the secondary aircraft (Table C-2; Figure C-2). Eighty-eight (83%) bowheads were found near-shore (1 to 5 km) east of Demarcation Bay, and two solitary bowheads (2%) were sighted offshore east of Barter Island. One group of sixteen bowheads (15%) was sighted approximately 33 km north of Barter Island (Flight C-11).

Bowheads were seen only in blocks 4 and 5 (Table C-3). Relative abundance (WPUE) ranged from 4.19 in block 5, to 2.61 in block 4. Only one bowhead was seen on transect in block 5; all other sightings were made while flying search surveys, thus there were insufficient sightings to analyze bowhead density.

Relatively high WPUE values were obtained throughout the month of September (Table C-1; see Figure 13). The highest WPUE (5.34) on 12 September resulted from a sighting of 25 feeding bowheads east of Demarcation Bay (Flight C-3). Additional WPUE peaks occurred on 11 September (4.44) and 27 September (4.80).

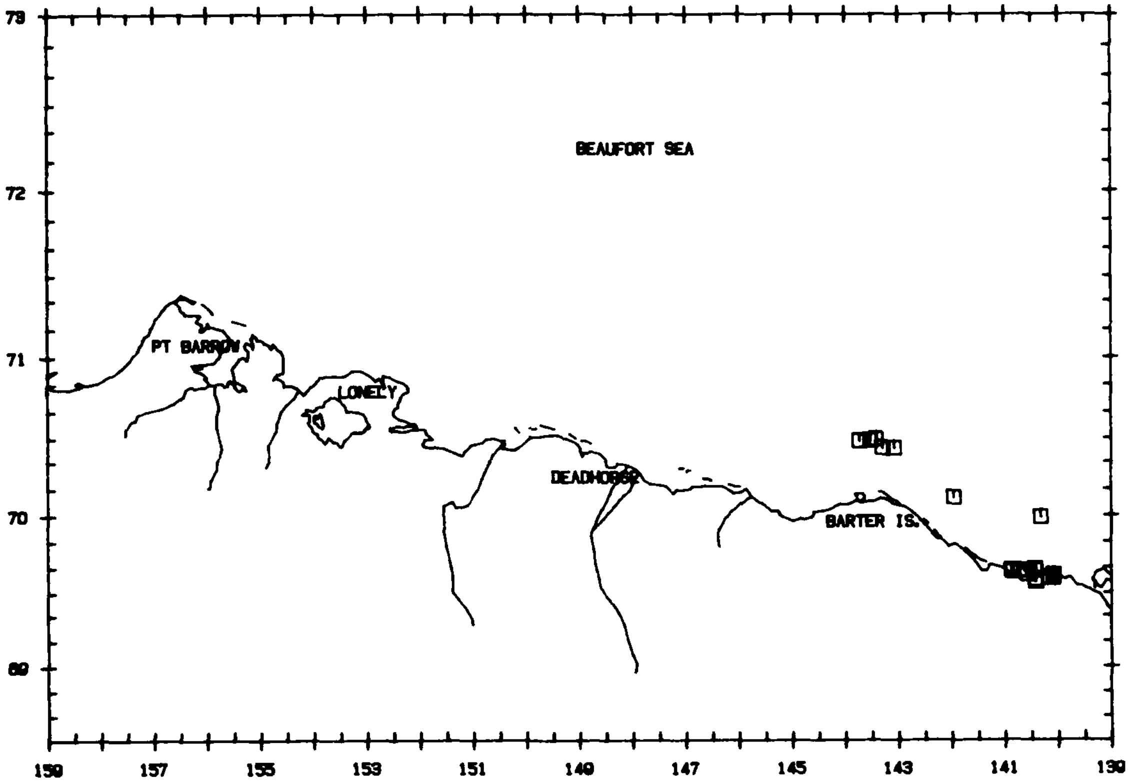


Figure C-2. Distribution of 19 sightings of 106 bowhead whales, N545N, September 1985.

Habitat Relationships and Behavior

All bowheads seen by the secondary aircraft were in shallow (<50 m) water ranging from 7 to 49 m. The mean depth was 20.8 m (s.d. 15.14), significantly shallower than mean depth for whales seen by the primary aircraft ($\bar{x} = 56.2$ m; $t = 1.79$, $p < 0.0385$) which conducted surveys further offshore. Seventy-four percent ($n = 79$) of all whales were in 0 to 10 percent ice coverage and twenty-five percent ($n = 26$) in 11 to 20 percent ice. One bowhead (1%) was in 99 percent ice (Flight C-7). The shallow depth and light ice coverage in which whales were seen by the secondary aircraft probably resulted from the fact that most flights were relatively close to shore, and all sightings were within 43 km of shore.

Table C-3. Relative abundance of N545N bowheads: whales per unit effort (WPUE) by block, September 1985.

Block	Flight*	Hours	Bowheads	WPUE
1	11	6.95	0	0.00
4	11	12.01	16	1.33
5	10	21.46	90	4.19
6	3	0.23	0	0.00
7	1	0.02	0	0.00
Block total	36	40.67	106	2.61
Canada	3	2.18	0	0.00
Grand Total	39	42.80	106	2.48

*Flight is any traverse of a block.

Sixty-four percent of all bowheads (n = 68) seen by the secondary aircraft were feeding. Bowheads not feeding were swimming (18%, n = 19), resting (7%, n = 7), milling (7%, n = 8), diving (2%, n = 2), or part of a cow-calf association (2%, n = 2).

All of the feeding bowheads were within 4 km of shore east of Demarcation Bay, an area that has been documented as being an important bowhead feeding area (Ljungblad et al., 1986). Groups of 18, 25, and 10 animals, respectively, were seen on three consecutive days in mid-September (Flights C-2 to C-4), and one group of 15 feeding bowheads was seen nine days later in the same location (Flight C-7). With the exception of the group of ten, which included 2 calves, all feeding bowheads were considered adults. None of the whales seen near Demarcation Bay after 22 September (Flight C-7) were considered feeding, but were instead swimming slowly or milling.

Eleven percent (n = 12) of all bowheads seen were judged to respond to the aircraft. Bowheads that did respond were all seen on 27 September (Flight C-11) north of Barter Island, and were milling, resting and swimming at the time of sighting. None of the whales seen east of Demarcation Bay throughout September were judged to respond to the aircraft, even though low ceilings and fog sometimes forced surveys to be flown at less than 457 m (1500 ft).

Four sonobuoys were dropped by the secondary aircraft, and bowhead sounds were recorded on two occasions. The results of an aural analysis of these calls is included in the main text (Tables 18 and 19, pages 57 and 59).

Recruitment

Five calves were seen among a total of 106 bowheads resulting in a ratio of calves to adults of 4.72% (Table C-4). This ratio should not be interpreted as a true GARR estimate because N545N surveys were limited in scope and did not attempt to sample all components of the population. Three calves were seen among a group of eight adult feeding whales on 13 September (Flight C-4). Two calves were seen on 24 September (Flight C-9); one was swimming in close association with a group of four adult whales and one was swimming close to a single adult, assumed to be the cow.

Table C-4. Summary of N545N bowhead calf sightings, September 1985.

Date	Flight	Latitude (N)	Longitude (W)	Number	Behavior
13 Sept	C-4	69° 38.3'	140° 50.1'	3	resting at surface in group of feeding whales
24 Sept	C-9	69° 35.8'	140° 04.8'	1	swimming in group of five
24 Sept	C-9	69° 37.0'	140° 04.3'	1	swimming close to cow

Other Species

Belukha Whale

Seven sightings of 64 belukhas were made by the secondary aircraft (Table C-5; see Figure 18). Belukhas were seen both singly and in groups of 2 to 25, and were found in depths ranging from 5 to 68 m ($\bar{x}$ = 30.6, s.d. = 28.0, n = 7).

Polar Bear

Five polar bears were seen by the secondary aircraft. One bear was at a kill site on 22 September (Flight C-7) at 70° 11.6'N, 144° 15.3'W', and four polar bears were seen at 70° 10.4'N, 141° 52.0W on 24 September (Flight C-9).

Table C-5. Summary of N545N belukha whale sightings, September 1985.

Flight	Date	Total Number	Latitude (N)	Longitude (W)
C-6	19 Sept	1	69° 49.3'	141° 40.7'
C-7	22 Sept	3	69° 44.1'	141° 15.2'
C-7	22 Sept	10	69° 23.0'	138° 45.7'
C-7	22 Sept	2	69° 34.9'	139° 31.2'
C-8	23 Sept	16	70° 25.1'	141° 29.6'
C-8	23 Sept	25	70° 25.9'	141° 28.0'
C-11	27 Sept	7	70° 23.9'	143° 49.1'

AERIAL SURVEY FLIGHT CAPTIONS, SURVEY TRACKS AND SIGHTING SUMMARIES, N545N, SEPTEMBER 1985

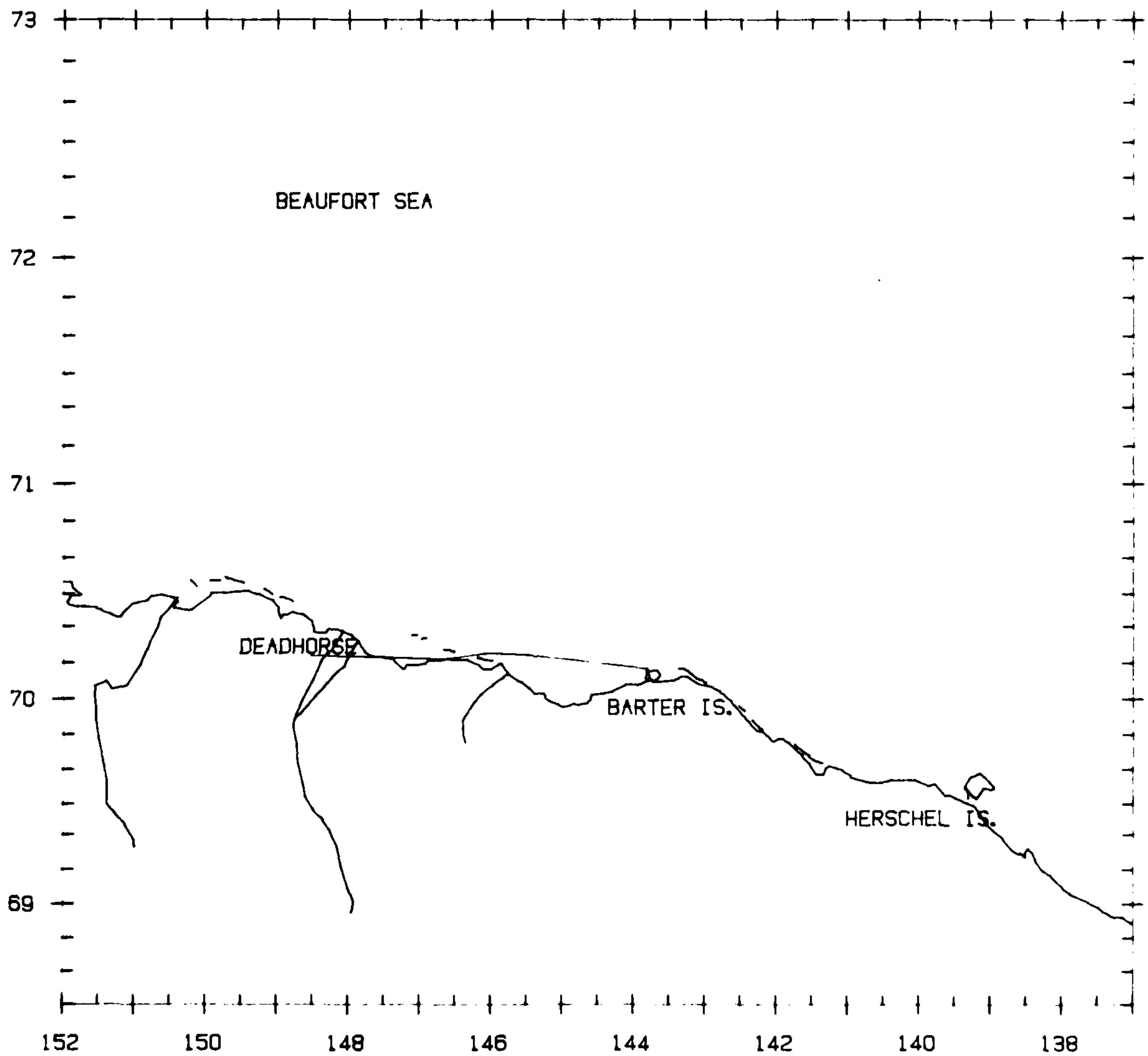
Each N545N flight is represented by a descriptive summary, including survey objectives and environmental conditions, and a survey track map with the location of all marine mammal sightings plotted. Flight track maps were prepared from the computerized data log recorded during each flight using methods described in Appendix A. Each symbol on the flight track charts represents a sighting of one or more animals. Additionally, summary information on bowhead whale sightings is presented beneath the flight caption in the tabularized format:

T#/C#	Total number of whales/total number of calves seen		
LAT/LONG	Location (latitude N/longitude W) in degrees, minutes, and tenths of minutes		
CUE	Sighting cue:		
	BO = Body	MP = Mud Plumes	
	BW = Blow	DY = Display	
	SP = Splash		
BEH	Behavior:		
	SW = Swim	DY = Display	SH = Spyhop
	DI = Dive	MT = Mate	TS = Tail-Slap
	RE = Rest	FE = Feed	BR = Breach
	MI = Mill	CC = Cow-Calf	NA = None
HDG	Heading in magnetic degrees; -- = whales displayed headings in all directions		
ICE	Ice coverage in percent		
SS	Sea State (Beaufort scale)		
DEPTH	Depth in meters		

A dash (-) indicates data were not recorded.

Flight C-1: 9 September 1985

Flight was planned as a search survey east of Deadhorse to the Canadian border, but was terminated at Barter Island due to fog and snow. Ice was present over most of the area surveyed, but its extent could not be determined due to fog. Sea state varied from Beaufort 00 to 02. No marine mammals were seen.



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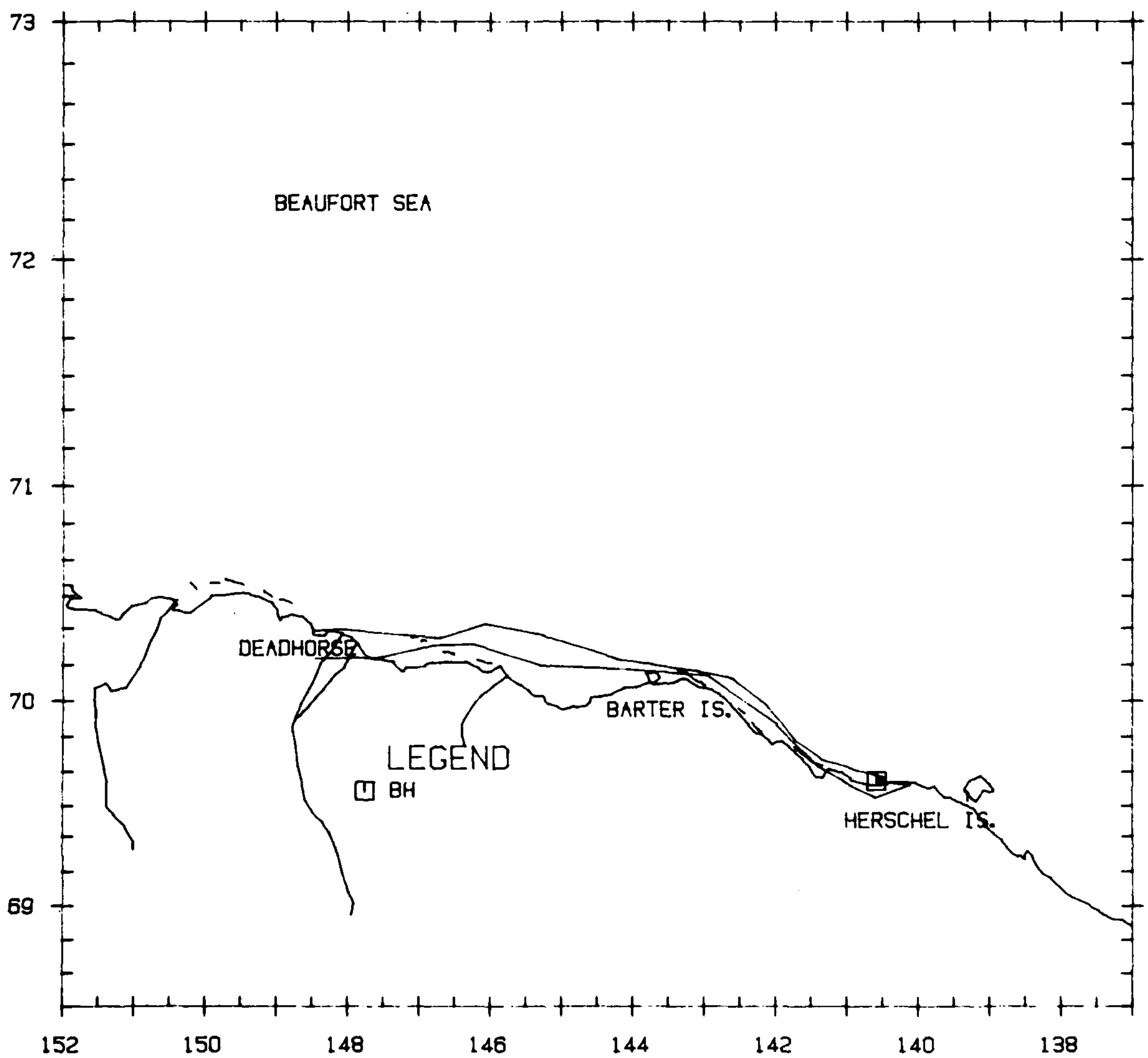
Flight C-2: 11 September 1985

Flight was a search survey east of Deadhorse to the Canadian border. Weather was clear with unlimited visibility. Ice coverage near-shore ranged from 50 to 99 percent between Deadhorse and Demarcation Bay (approx. 141°30'W). East of Demarcation Bay ice coverage varied from 0 to 20 percent. Sea state was generally Beaufort 00 to 02. Eighteen bowheads were seen approximately 26 km east of Demarcation Bay. All whales were seen within 4 km of shore and appeared to be feeding. One sonobuoy was dropped, but few whale calls were heard.

T#/C#	LAT	LONG	CUE	BEH	HDG	ICE	SS	DEPTH
18/0	69°37.2'	140°34.5'	BO	FE	--	5	B2	7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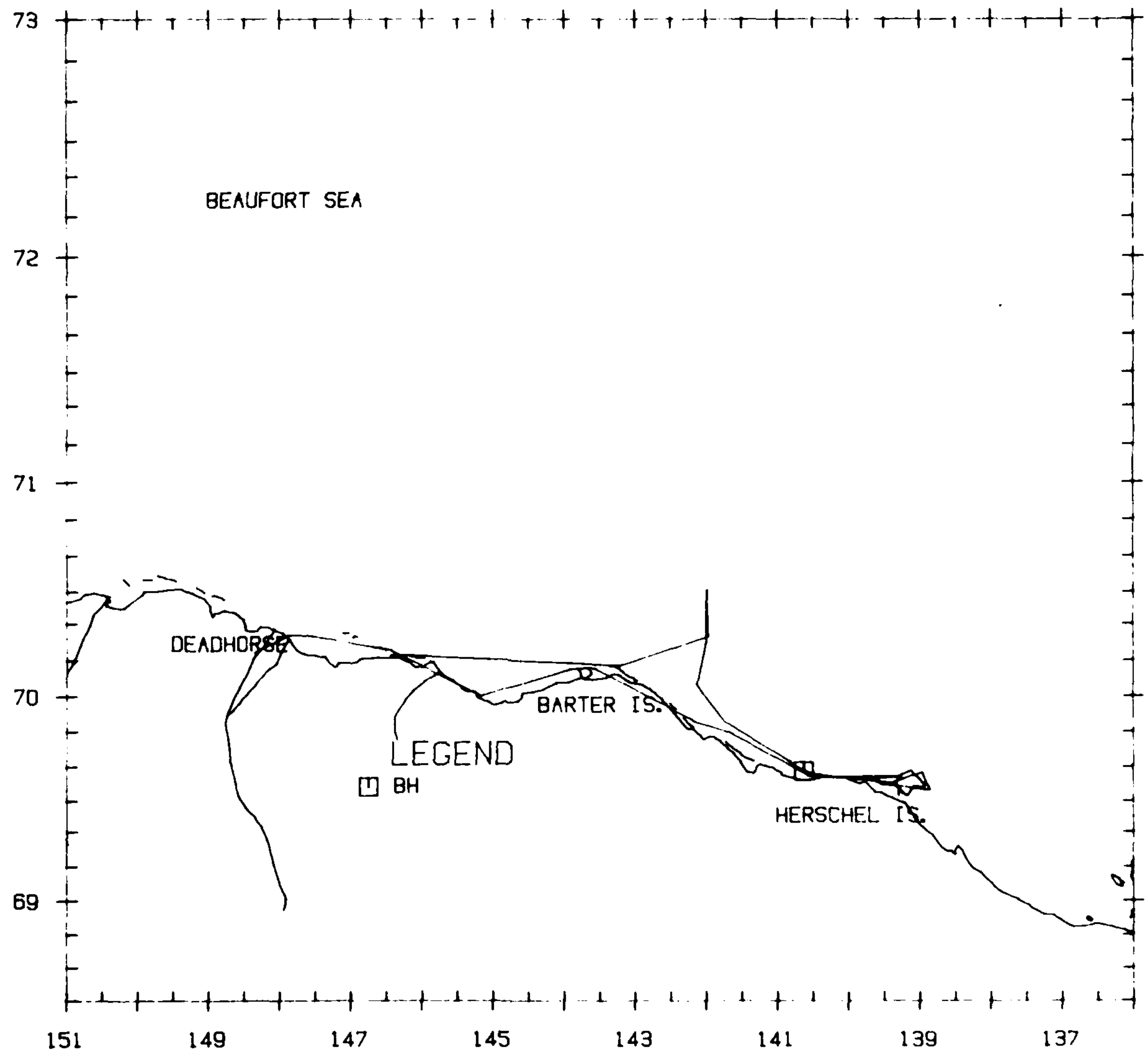
Flight C-3: 12 September 1985

Flight was a search survey east of Deadhorse, a transect north along 142°W, and a search to Herschel Island, Canada. Weather was high overcast with unlimited visibility. Ice coverage ranged from 20 to 80 percent between Deadhorse and Barter Island. East of Barter Island, ice coverage varied from 0 to 20 percent. Sea state ranged from Beaufort 00 to 03. Twenty-five bowheads were seen approximately 22 km east of Demarcation Bay. Most were feeding and milling and some appeared to be traveling slowly to the east.

T#/C#	LAT	LONG	CUE	BEH	HDG	ICE	SS	DEPTH
25/0	69°38.7'	140°37.4'	BO	FE SW MI	--	5	B3	7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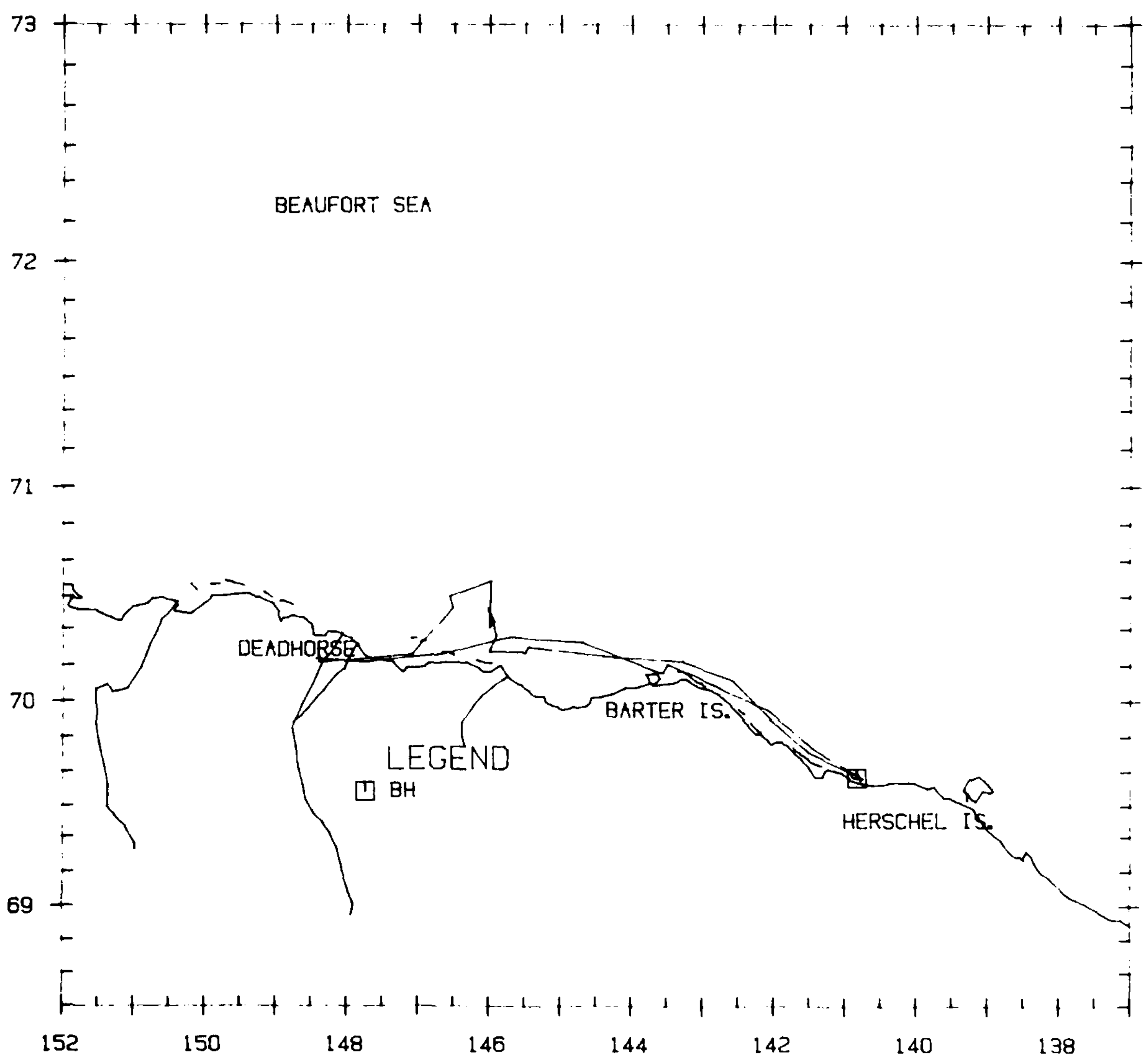
Flight C-4: 13 September 1985

Flight was a search survey east of Deadhorse to Komakuk, Canada (approx. 140°10'W). Weather was clear with unlimited visibility. Ice coverage ranged from 50 to 80 percent between Deadhorse and Barter Island, and from 0 to 30 percent between Barter Island and Komakuk. Sea state varied from Beaufort 00 to 03. Ten bowheads, including 3 calves, were seen approximately 19 km east of Demarcation Bay. The whales were feeding, resting, and milling within 2 km of shore. A sonobuoy was dropped but few calls were heard.

T#/C#	LAT	LONG	CUE	BEH	HDG	ICE	SS	DEPTH
10/3	69°38.3'	140°50.1'	BO	FE MI RE	--	10	B0	7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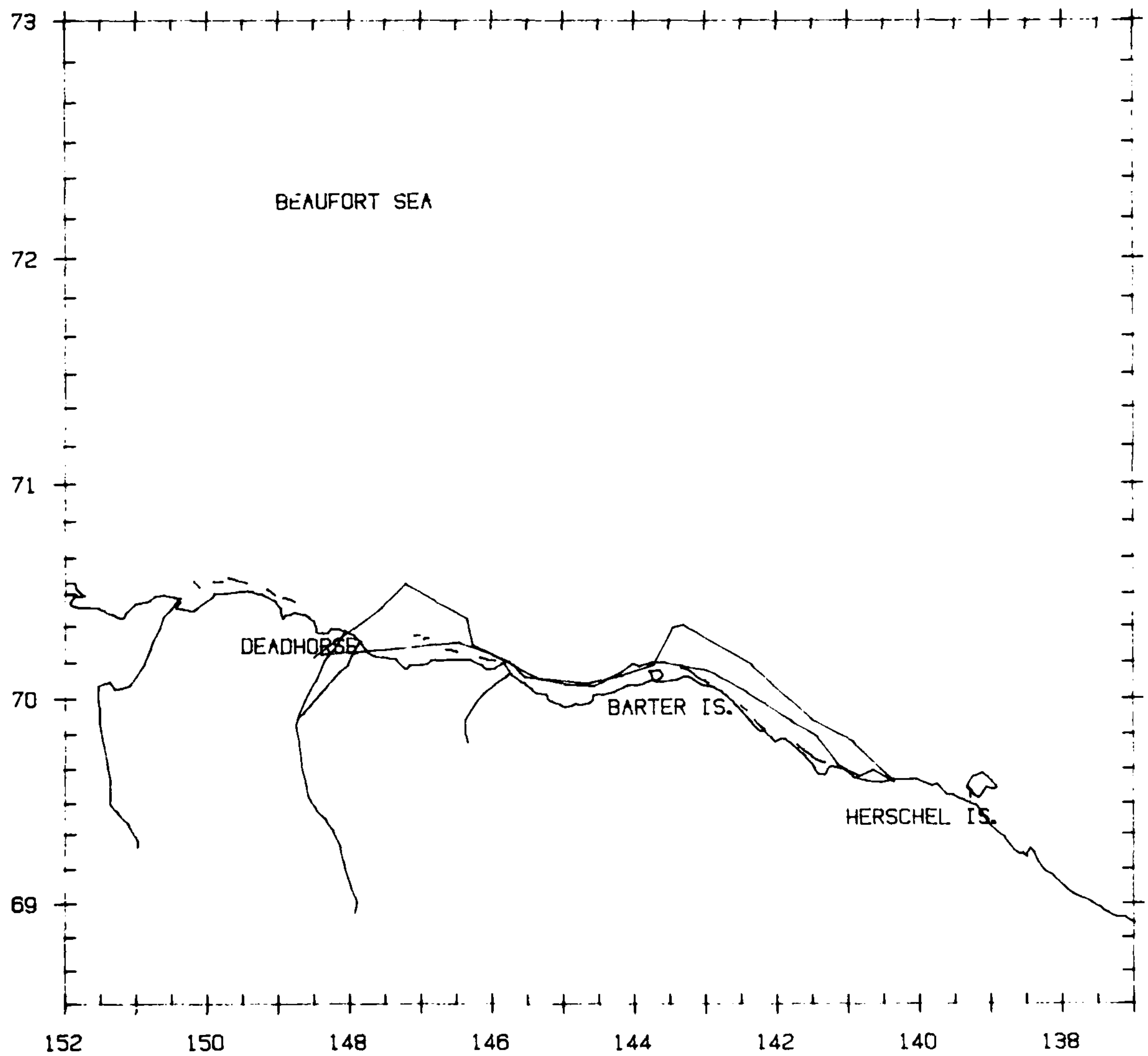
Flight C-5: 18 September 1985

Flight was a search survey east of Deadhorse to Komakuk. Weather was clear with high overcast and unlimited visibility. Following the storm of the previous week, ice coverage was extensive and ranged from 80 to 99 percent from Deadhorse to Demarcation Bay except for a narrow open water corridor within 1 km of shore. East of Demarcation Bay, ice coverage varied from 30 to 50 percent. Sea state ranged from Beaufort 00 to 03. No marine mammals were seen.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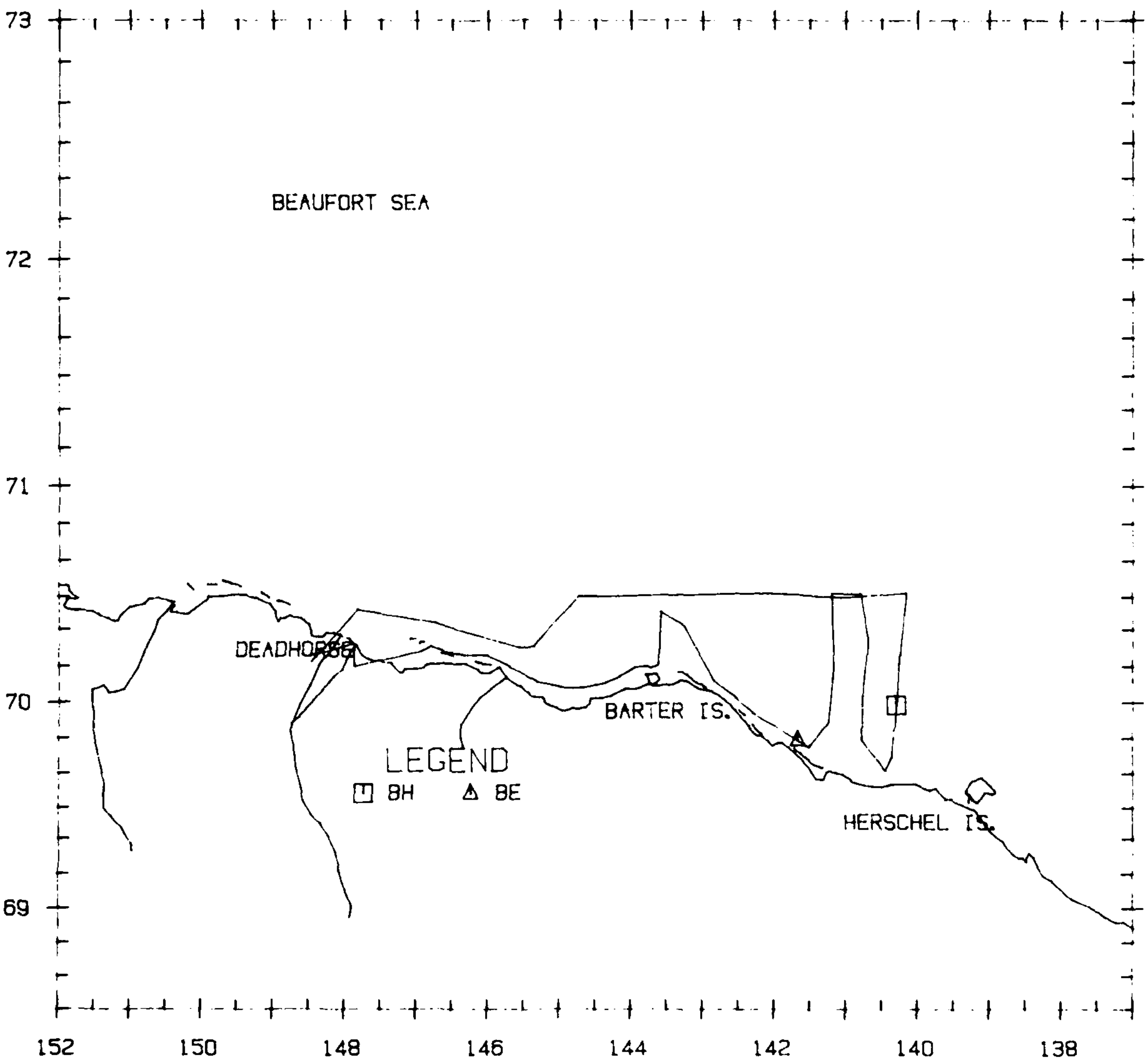
Flight C-6: 19 September 1985

Flight was a search survey east of Deadhorse to Demarcation Bay, including three offshore transects in the eastern half of block 5. Weather was overcast with unlimited visibility. Ice coverage ranged from 20 to 99 percent between Deadhorse and Barter Island, with open water extending east of Barter Island and offshore. Sea state varied from Beaufort 02 to 03. One bowhead whale was seen swimming north approximately 44 km offshore in open water. A belukha was also seen, swimming east approximately 5 km from shore.

T#/C#	LAT	LONG	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	69°59.3'	140°18.7'	BO	SW	360	0	B2	49



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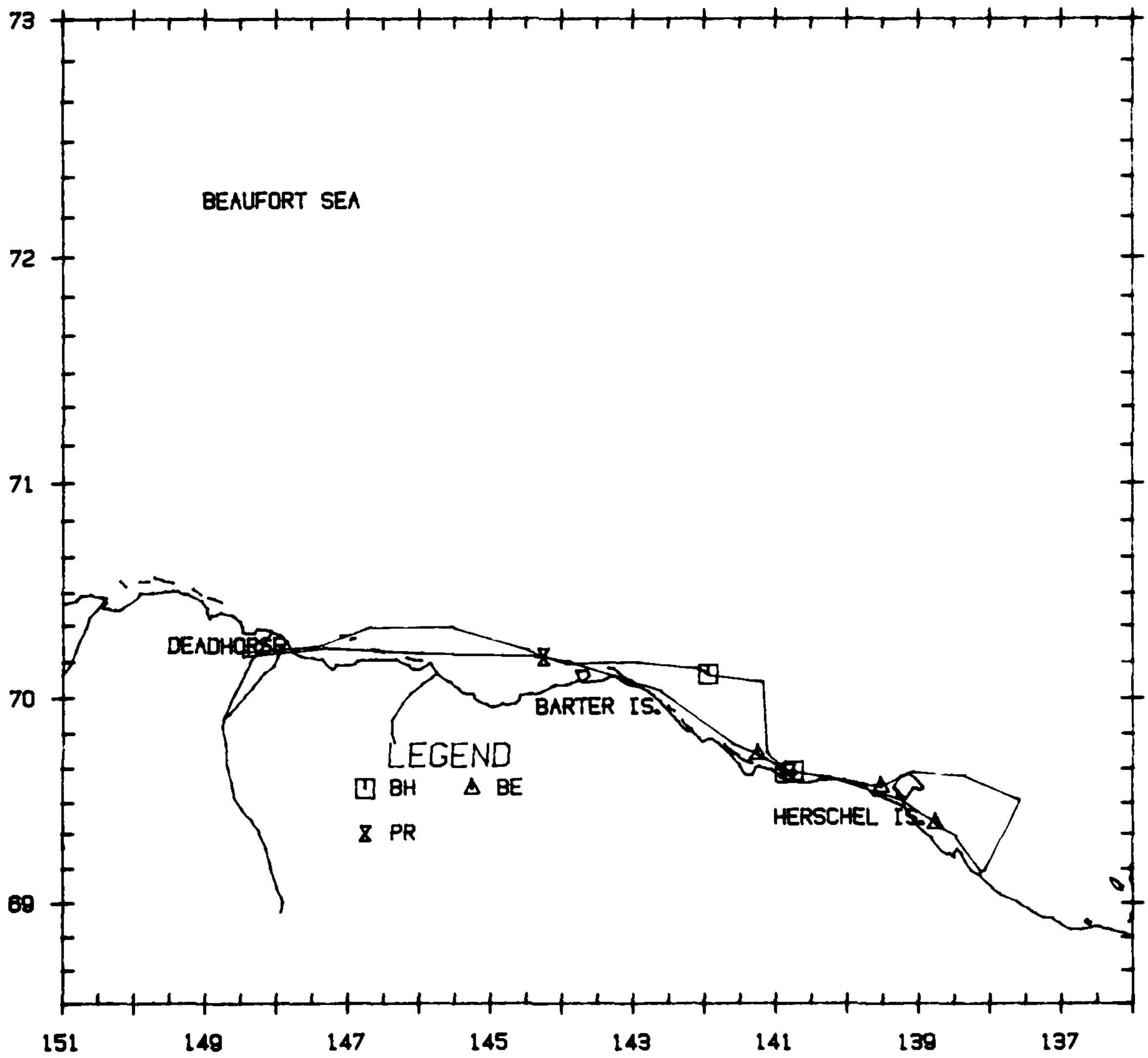
Flight C-7: 22 September 1985

Flight was a search survey east of Deadhorse to Kay Point, Canada (approx. 138°W). Weather was clear with unlimited visibility. Ice coverage ranged from 20 to 100 percent between Deadhorse and Demarcation Bay, with open water further to the east. Sea state was Beaufort 02 to 03 east to Herschel Island where strong winds caused higher sea states of Beaufort 04 to 05. Approximately 15 bowheads were seen milling and feeding 19 km east of Demarcation Bay within 4 km of shore. A single bowhead was also seen surfacing in a small pond within 99 percent ice approximately 35 km from shore. Three sightings of 15 belukhas within 4 km of shore and one sighting of a polar bear at a kill site were also made.

T#/C#	LAT	LONG	CUE	BEH	HDG	ICE	SS	DEPTH
15/0	69°38.8'	140°51.6'	BO	MI/FE	--	10	B2	7
1/0	70°06.7'	141°56.7'	BO	RE	270	99	B0	38



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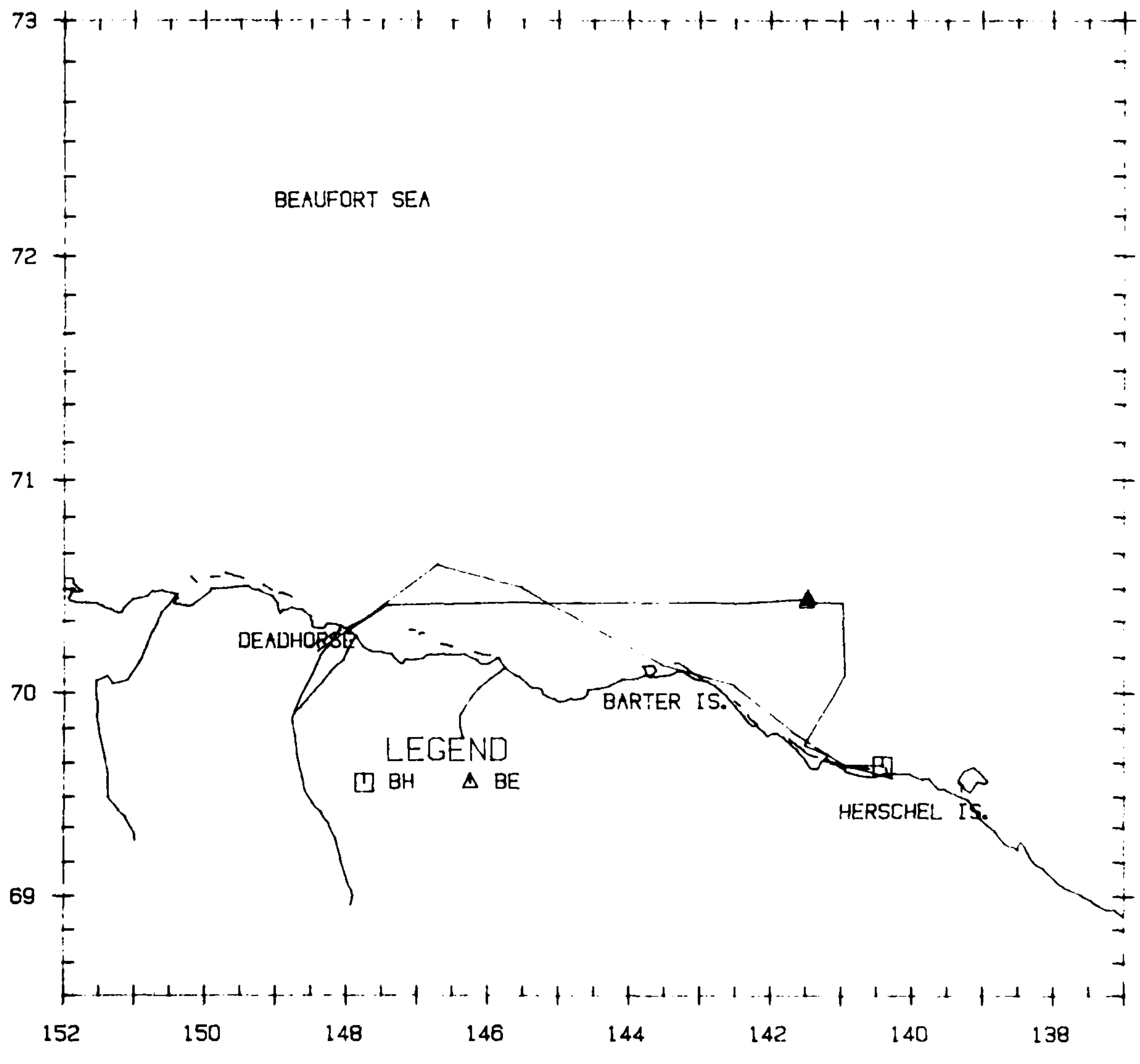
Flight C-8: 23 September 1985

Flight was a search survey east of Deadhorse to Komakuk. Weather was clear with unlimited visibility. Ice coverage was 50 to 99 percent between Deadhorse and Demarcation Bay. Further east the ice ranged from 5 to 10 percent with mostly open water in Canada. Sea state varied from Beaufort 00 to 02. Eight bowhead whales were milling and traveling slowly approximately 11 km west of Komakuk within 4 km of shore. A sonobuoy was dropped and whale calls were recorded. Two sightings of 41 belukhas were made in 80 percent ice approximately 80 km from shore.

T#/C#	LAT	LONG	CUE	BEH	HDG	ICE	SS	DEPTH
8/0	69°39.2'	140°24.6'	BO	MI/SW	--	10	B2	7



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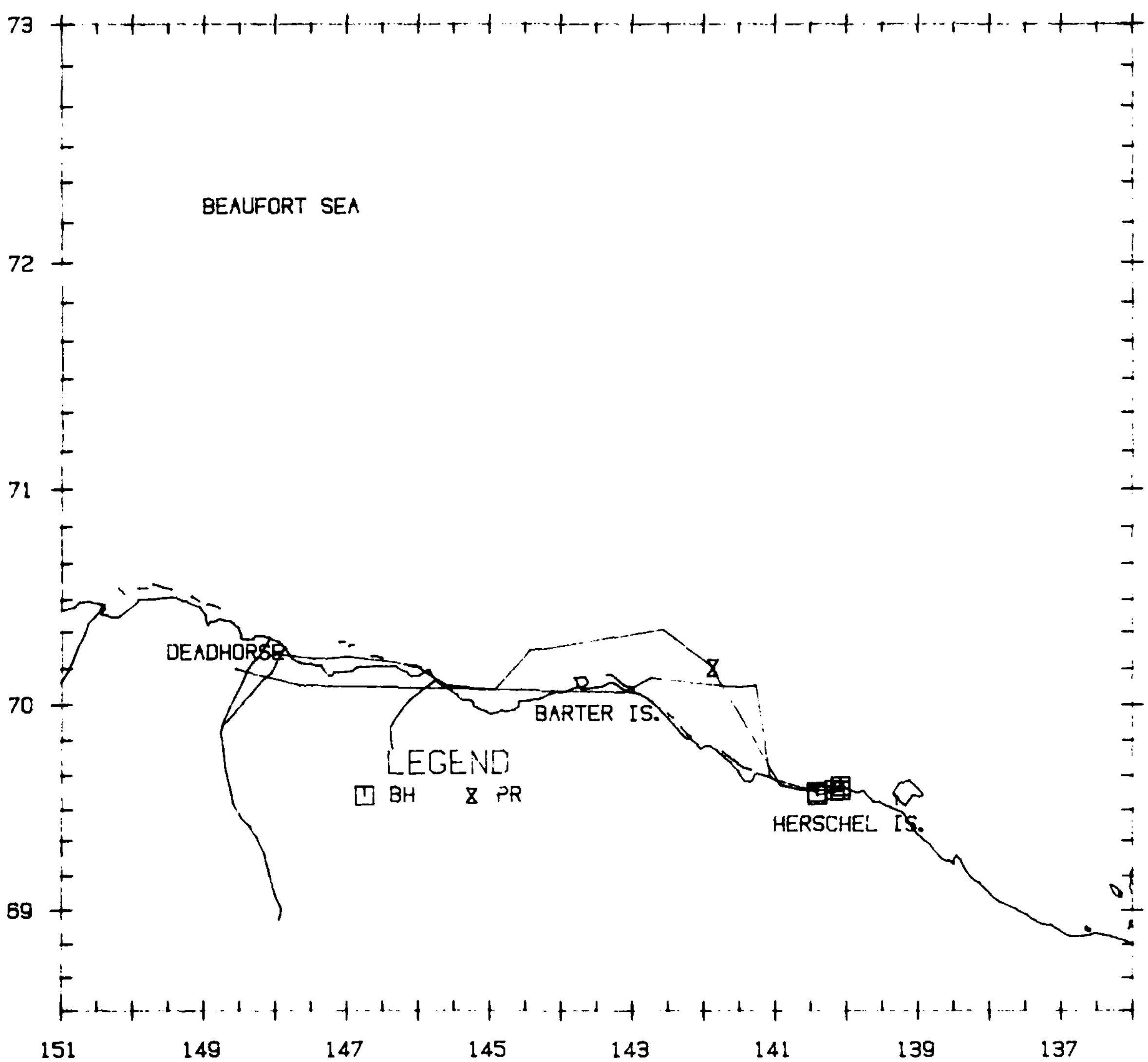
Flight C-9: 24 September 1985

Flight was a search survey east of Deadhorse to Komakuk. The weather was overcast with snow near Deadhorse, but became progressively clearer east of Barter Island where visibility was unlimited. Ice was 50 to 80 percent between Deadhorse and Barter Island, and varied from 5 to 20 percent farther east. Sea state ranged from Beaufort 01 to 03. Five sightings of 10 bowheads, including 2 calves, were made from 2 km to 13 km east of Komakuk and within 4 km of shore. The whales were swimming slowly with variable headings. Four polar bears were sighted on 99 percent ice approximately 19 km north of Barter Island.

T#/C#	LAT	LONG	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	69°35.7'	140°09.4'	BO	SW	90	20	B1	16
5/1	69°35.8'	140°04.8'	BO	SW	--	20	B1	16
2/1	69°37.0'	140°04.3'	BO	C/C	--	20	B1	16
1/0	69°34.3'	140°24.3'	BO	SW	270	20	B1	7
1/0	69°35.2'	140°24.5'	BO	SW	330	20	B1	7



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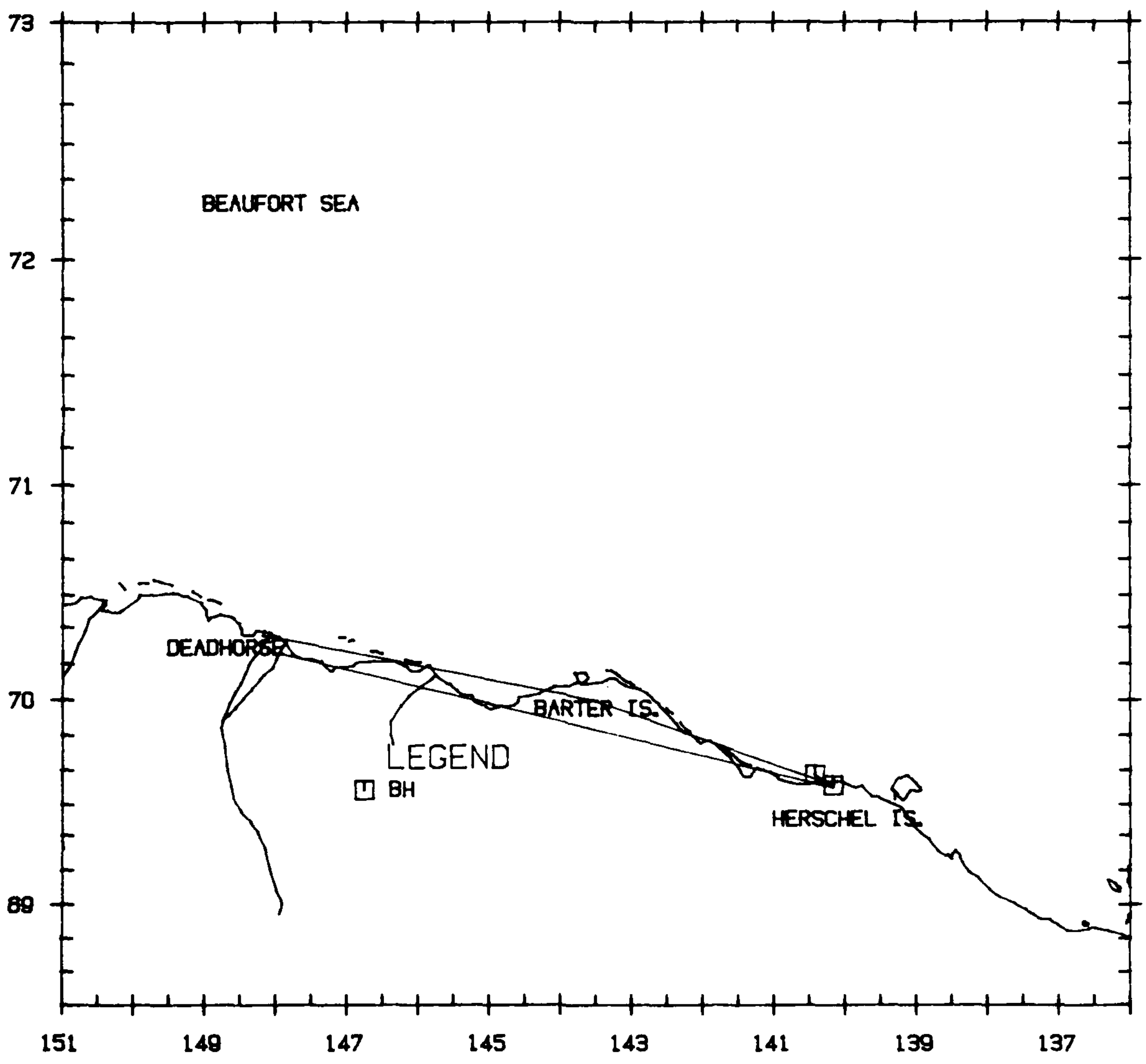
Flight C-10: 25 September 1985

Flight was a search survey east of Deadhorse to Komakuk. The weather was overcast with good visibility despite some patchy fog west of Barter Island. Ice coverage averaged 20 percent east of Demarcation Bay. Sea state ranged from Beaufort 02 to 03. Two bowheads were seen milling in 10 percent ice; one approximately 13 km west of Komakuk and the other approximately 2 km east of Komakuk. Both whales were within 2 km of shore and were diving for 20 minutes or more between surfacings.

T#/C#	LAT	LONG	CUE	BEH	HDG	ICE	SS	DEPTH
1/0	69°38.8'	140°25.0'	BO	MI	90	10	B2	7
1/0	69°35.7'	140°09.3'	BO	MI	220	10	B2	16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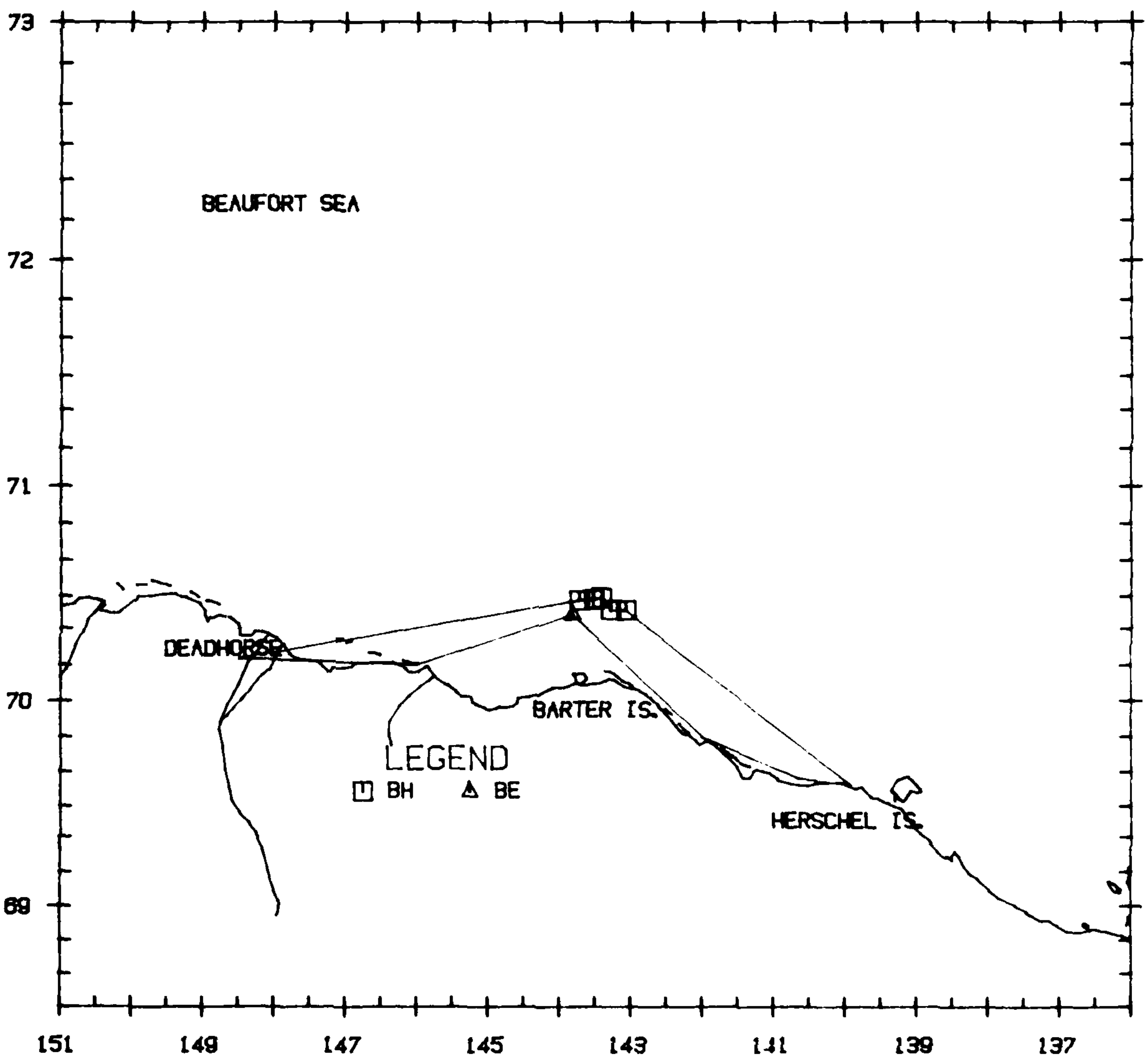
Flight C-11: 27 September 1985

Flight was a search survey east of Deadhorse to Komakuk. The weather was clear with unlimited visibility. Ice coverage varied from open water to 80 percent broken floe and grease ice west of Barter Island. Sea state was Beaufort 01 to 03. Five sightings of 16 bowheads were made in 20 percent ice approximately 33 km north of Barter Island. The whales were resting, swimming slowly, diving, and milling at the surface. No bowheads were sighted east of Demarcation Bay where they had been seen earlier in the season. Seven belukhas, including three calves, were also seen.

T#/C#	LAT	LONG	CUE	BEH	HDG	ICE	SS	DEPTH
6/0	70°25.0'	143°04.0'	BO	MI	--	20	B1	37
4/0	70°25.1'	143°17.0'	BO	RE	180	20	B1	37
2/0	70°28.3'	143°24.4'	BO	DI	30	20	B1	37
2/0	70°27.8'	143°30.9'	BO	SW	240	20	B1	37
2/0	70°27.6'	143°43.2'	BO	RE	--	20	B1	40



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APPENDIX D

ERRATUM TO 1979-85 AERIAL SURVEY DATA

CONTENTS

TABLES

INTRODUCTION

Aerial surveys to document endangered whale distribution and abundance in the northern Bering, eastern Chukchi and Alaskan Beaufort Seas have been completed each year since 1979 by the Naval Ocean Systems Center (NOSC) of San Diego, CA. Summaries of these survey efforts have been published each year in NOSC technical documents or reports (Ljungblad et al., 1980; Ljungblad, 1981; Ljungblad et al., 1982, 1983, 1984, 1985). Data collection and analysis techniques have improved and become more automated each year, particularly so since the introduction of an onboard microcomputer in 1982. The result was a cleaner and more refined data base. Revising the data, however, has meant that some of the data reported for past years, particularly 1979-81, has changed, albeit for the better.

Changes in the data occurred in total number of hours flown, total number of whales seen, depths at sightings, and general data formatting. These changes resulted from reevaluating the raw data, more exact data analysis via computer programs not available in past years, and updating the entire 7-year data base into the current format. This appendix highlights the changes in the data for 1979-84, and should be a useful tool in interpreting the complete data base. The appendix is arranged as follows:

A. Total number of hours of survey effort: spring, summer and fall, 1979-85

B. Total number of bowhead whales seen: spring, summer and fall, 1979-85

C. Bowhead whale abundance estimates (WPUE), 1979-85

D. Total number of gray whales seen: spring, summer and fall, 1979-85

E. General changes in data due to data format updating

A. Total number of hours of survey effort: spring, summer, and fall, 1979-85

Annual total number of survey effort hours has changed each season for the following reasons:

1. Survey effort was calculated by hand in 1979-83 and with a hand-entry computer program in 1984. In 1985, an automated computer program was available which calculated total number of survey hours for each flight. Additional programs further divided flight effort into total number of hours in each sea and in each survey block. These programs enabled us to calculate more accurate survey times for each season for any year.

2. Prior to running the computer programs, the raw data were checked for formatting errors and fixed so that all flights, regardless of the year, were identical in format. Flights which were discontinuous (with a landing and launching taking place in the middle of the flight) were reformatted such that time on the ground was not included in the total survey time as it had been when survey times were hand-calculated. As a result, the total survey times for 1979-84 listed in Tables 21, 25, and D-1 are generally smaller than those in Ljungblad et al. (1985).

3. The amount of survey time spent in each sea is slightly different from that reported in NOSC TR 1046 (Ljungblad et al., 1985), since previously 156°30'W was the demarcation between the Beaufort and Chukchi Seas and 65°30'N the demarcation between the Chukchi and Bering Seas. The demarcation lines now used are 157°W for the Beaufort-Chukchi Sea and 66°N for the Chukchi-Bering Sea, since these better coincide with our study blocks (see Figure 1).

4. There was no spring field season in 1985, and as such no spring section to this report. Therefore, updated spring survey times are given in Table D-1.

Table D-1. Summary of hours: minutes of flight effort by sea, spring 1979-85.

Sea	1979	1980	1981	1982	1983	1984	1985	Total	(%)
Beaufort	31:03	32:20	55:05	40:43	53:37	9:37	-	222:25	(50)
Chukchi	6:20	10:49	12:53	12:43	4:40	30:43	-	78:08	(17)
Bering	-	26:27	73:34	29:46	6:06	12:52	-	148:45	(33)
Total	37:23	69:36	141:32	83:12	64:23	53:12	-	449:18	(100)

5. Survey times for summer 1980 and 1981 reported in Table 21 of this report are higher than those reported in Table 36 of NOSC TR 1046 (Ljungblad et al., 1985) because June surveys were not included in Ljungblad et al. (1985) but were in Table 21.

6. Total survey time for fall 1980 reported in Table 25 of this report includes survey time from November 1980, which were not included in Table 32 of NOSC TR 1046 (Ljungblad et al., 1985).

B. Total number of bowhead whales seen: spring, summer, and fall, 1979-85.

Some discrepancies were noted in original reports for the years 1979-81, with regard to the total number of bowheads seen. To correct these discrepancies, the raw flight and sighting data for all seasons 1979-81 were reevaluated. Three main reasons for such discrepancies were noted:

A. typographical and/or keypunch errors;

B. resighted whales were sometimes coded as original sightings and included in the total number, yielding higher than normal totals;

C. some whales in the original raw data base were bypassed, or were incorrectly coded as resights and not incorporated in the final data base or subsequent report, yielding lower than normal totals.

There were no changes in total number of bowheads for years 1982-85. The original and revised total number of bowheads seen per season per year 1979-85 are summarized in Table D-2. For each season in which changes in the total number of whales occurred, two tables are included: one which lists the original total, reason for that total and original published source as well as the revised total and published source; and a second table which itemizes, by season, changes in the total number of bowheads seen per each of the three discrepancy reasons (A-C) outlined above.

Table D-2. Summary of total number of bowheads seen, 1979-85.

Year	Season	Original	Source	Revised	Source
1979	Fall	237	NOSC TD 314: Ljungblad et al., 1980	197	This report (NOSC TR 1111)
1980	Spring	705	NOSC TD 449: Ljungblad, 1981	662	NOSC TR 1046: Ljungblad et al., 1985
	Summer	16	NOSC TD 449: Ljungblad, 1981	16	(no change)
	Fall	45	NOSC TD 449: Ljungblad, 1981	46	This report (NOSC TR 1111)
1981	Spring	1222	NOSC TD 486 Ljungblad et al., 1982	1239	NOSC TR 1046: Ljungblad et al., 1985
	Fall	176	NOSC TD 486: Ljungblad et al., 1982	288	This report (NOSC TR 1111)
1982	Spring	265	NOSC TD 605: Ljungblad et al., 1983	265	(no change)
	Fall	490	NOSC TD 605: Ljungblad et al., 1983	490	(no change)
1983	Spring	223	NOSC TR 955: Ljungblad et al., 1984	223	(no change)
	Fall	172	NOSC TR 955: Ljungblad et al., 1984	172	(no change)
1984	Spring	237	NOSC TR 1046: Ljungblad et al., 1985	237	(no change)
	Fall	380	NOSC TR 1046: Ljungblad et al., 1985	380	(no change)
1985	Fall	139	This report (NOSC TR 1111)	139	(no change)
Spring total		2652		2626	
Summer Total		16		16	
Fall		1639		1712	
TOTAL		**4307**		**4354**	

Table D-3. Summary table for fall 1979: original and revised total number of bowheads seen.

	NUMBER OF BOWHEADS			
	Original		Revised	
Source	NOSC TD 314: Ljungblad et al., 1980		This report (NOSC TR 1111)	
August	5	(p. 4)	7	
September	82	(p. 9)	60	
October	162	(p. 11)	130	
	249	(reported page 15, para 2)	197	(see Table 23)
	-2	(two too many whales reported in Table 4 for 14 October - 42 whales are listed for flight)		
	247			
	-10	(incidental sightings made by NARL pilot repeated on page 10, Table 3)		
TOTAL	**237**		**197**	

Table D-4. Summary table for fall 1979: reasons for changes in the total number of bowheads seen.

Reason for Change	Difference in Total No. of Bowheads
A. typographical and/or keypunch errors	-1
B. resighted bowheads included as original sightings	-42
C. original-sight bowheads not included in annual report	+3
TOTAL DIFFERENCE	**-40**

Total Bowheads Fall 1979

237	from original report
-40	total difference
197	**correct total**

Table D-5. Summary table for spring 1980: original and revised total number of bowheads seen.

	NUMBER OF BOWHEADS Original	Revised
Source	NOSC TD 449: Ljungblad, 1981	NOSC TR 1046 Ljungblad et al., 1985
	705 (Appendix C)	662
TOTAL	**705**	**662**

Table D-6. Summary table for spring 1980: reasons for changes in the total number of bowheads seen.

Reason for Change	Difference in Total No. of Bowheads
A. typographical and/or keypunch errors	-39
B. resighted bowheads included as original sightings	-9
C. original sight bowheads not included in annual report	+5
TOTAL DIFFERENCE	**-43**

Total Bowheads Spring 1980

705	from original report
-43	total difference
662	**correct total**

Table D-7. Summary table for fall 1980: original and revised total number of bowheads seen.

	NUMBER OF BOWHEADS			
	Original		Revised	
Source	NOSC TD 449: Ljungblad, 1981		This report (NOSC TR 1111)	
August	0	(Appendix C)	0	(see Table 23)
September	33	(Appendix C)	34	(see Table 23)
October	12	(Appendix C)	12	(see Table 23)
TOTAL	**45**		**46**	

Table D-8. Summary table for fall 1980: reasons for changes in total number of bowheads seen.

Reason for Change	Difference in Total No. of Bowheads
A. typographical and/or keypunch errors	+1

TOTAL DIFFERENCE +1

Total Bowheads Fall 1980

45 from original report
+1 total difference

46 correct total

Table D-9. Summary table for spring 1981: original and revised total number of bowheads seen.

	NUMBER OF BOWHEADS Original	Revised
Source	NOSC TD 486: Ljungblad et al., 1982	NOSC TR 1046 Ljungblad et al., 1985
	1222 (pp. A-3 to A-6)	1239
TOTAL	**1222**	**1239**

Table D-10. Summary table for spring 1981: reasons for changes in the total number of bowheads seen.

Reason for Change	Difference in Total No. of Bowheads
A. typographical and/or keypunch errors	+21
B. resighted bowheads included as original sightings	-4
TOTAL DIFFERENCE	**+17**

Total Bowheads Spring 1981

1222	from original report
+17	total difference
1239	**correct total**

Table D-11. Summary table for fall 1981: original and revised total numbers of bowheads seen.

	NUMBER OF BOWHEADS Original	Revised
Source	NOSC TD 486: Ljungblad et al., 1982	This report (NOSC TR 1111)
August	2 (Table A-2)	2 (see Table 26)
September	125 (Table A-2)	232 (see Table 26)
October	49 (Table A-2)	54 (see Table 26)
TOTAL	**176**	**288**

Table D-12. Summary table for fall 1981: reasons for changes in the total number of bowheads seen.

Reason for Change	Difference in Total No. of Bowheads
C. original-sight bowheads included in summary tables that accompanied daily flight tracks in Appendix A were not included in summary Table A-2.	+112

TOTAL DIFFERENCE +112

Total Bowheads Fall 1981

176	from original report
+112	total difference
288	**correct total**

Table D-13. Summary table for fall 1982.

NUMBER OF BOWHEADS

	Original		Revised
Source	NOSC TR 605: Ljungblad et al., 1983		This appendix
August	145	(Table XII)	145
September	297	(Table XII)	301*
October	48	(Table XII)	44*
TOTAL	**490**		**490**

Although there was no change in the total number of bowheads, four bowheads seen on 30 September* were included with October bowheads in Table XII and Figure 17 (Ljungblad et al., 1983).

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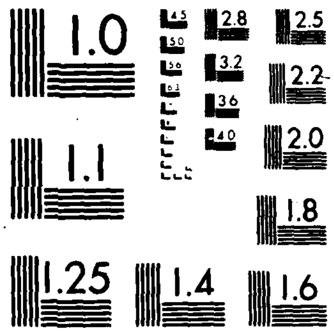
1.0
2.8
2.5
3.2
2.2
3.6
4.0
2.0
1.1
1.8
1.25
1.4
1.6

C. Bowhead whale abundance estimates (WPUE), fall 1979-84.

Bowhead whale abundance estimates have been calculated each fall since 1982. Both survey effort (hours) per block and number of bowheads per block were calculated by hand until 1985, when computer programs were generated which calculated exact values for these parameters. The combined data set resulted in updated WPUE values (see Table 27). In some instances, the number of hours per block or number of whales per block changed, and in some cases both did. The values presented in Table 27 are the revised values and should be used in lieu of previous abundance estimates for future reference.

D. Total number of gray whales seen: spring, summer, and fall, 1980-85

The total number of gray whales seen per season per year have changed for the same reasons (A-C) that total number of bowheads changed. Most of the discrepancies occurred in the 1980 data set. The following table (Table D-14) is a summary account of the total number of gray whales seen by season each year 1980-85. Additionally, for each season in which changes in the total number of whales occurred, two tables were included: one which lists the original total, reason for that total, and original published source, as well as the revised total and published source; and a second table which itemizes, by season, changes in the total number of bowheads seen per each of the three (A-C) reasons.

Table D-14. Summary of total number of gray whales seen, 1980-85.

Year	Season	Original	Source	Revised	Source
1980	Spring	6	NOSC TD 449: Ljungblad, 1981	6	(no change)
	Summer	10	NOSC TD 449: Ljungblad, 1981	48	This report (NOSC TR 1111)
	Fall	256	NOSC TD 449: Ljungblad et al., 1982	288	This report (NOSC TR 1111)
1981	Spring	153	NOSC TD 486: Ljungblad et al., 1982	153	(no change)
	Summer	338	NOSC TD 486: Ljungblad et al., 1982	339	This report (NOSC TR 1111)
	Fall	55	NOSC TD 486: Ljungblad et al., 1982	55	(no change)
1982	Spring	2	NOSC TR 605: Ljungblad et al., 1983	2	(no change)
	Summer	321	NOSC TR 605: Ljungblad et al., 1983	321	(no change)
	Fall	26	NOSC TR 605: Ljungblad et al., 1983	26	(no change)
1983	Summer	1026	NOSC TR 955: Ljungblad et al., 1984	1026	(no change)
	Fall	26	NOSC TR 955: Ljungblad et al., 1984	26	(no change)
1984	Summer	51	NOSC TR 1046: Ljungblad et al., 1985	51	(no change)
	Fall	115	NOSC TR 1046: Ljungblad et al., 1985	115	(no change)
1985	Summer	705	This report (NOSC TR 1111)	705	(no change)
Spring Total		161		161	
Summer Total		2506		2545	
Fall Total		423		455	
TOTAL		3090		3161	

Table D-15. Summary table for 1980: original and revised total number of gray whales seen.

	NUMBER OF GRAY WHALES			
	Original		Revised	
Source	NOSC TD 449: Ljungblad et al., 1981		This report (NOSC 1111)	
Spring	6		6	
Summer	10	(fifty were reported in Table C-2 but only ten were actually listed in Appendix C)	48	(see Table 23)
Fall	256	(271 were reported in Table C-2 but only 256 were actually listed in Appendix C)	288	(see Table 46)
TOTAL	**272**		**342**	

Table D-16. Summary table for summer 1980: reasons for changes in the total number of gray whales seen.

Reason for Change	Difference in Total No. of Gray Whales
A. typographical and/or keypunch errors	+38
TOTAL DIFFERENCE	**+38**

Total Gray whales summer 1980

10	from original report
+38	total difference
48	**correct total**

Table D-17. Summary table for fall 1980: reasons for changes in the total number of gray whales seen.

Reason for Change	Difference in Total No. of Gray Whales
C. original-sight gray whales not included in annual report	+32
TOTAL DIFFERENCE	**+32**

Total gray whales fall 1980

256	from original report
+32	total difference
288	**correct total**

Table D-18. Summary table for 1981: original and revised total number of gray whales seen.

NUMBER OF GRAY WHALES

	Original	Revised	
Source	NOSC TD 486 Ljungblad et al., 1982	This report	
Spring	153	153	
Summer	338	339	(see Table 23)
Fall	55	55	
TOTAL	**546**	**547**	

D-19. Summary table for summer 1981: reasons for changes in the total number of gray whales seen.

Reason for Change	Difference in Total No. of Gray Whales
C. original-sight gray whales not included in annual report	+1
TOTAL DIFFERENCE	**+1**

Total gray whales summer 1981

338	from original report
+1	total difference
339	**correct total**

Table D-20. Summary table for 1982: original and revised total number of gray whales seen.

NUMBER OF GRAY WHALES

	Original		Revised	
Source	Ljungblad et al., 1983		This report	
Spring	2		2	
Summer	321	(320 were reported in Table A-1, but 321 were actually reported in flight captions)	321	(see Table 23)
Fall	26		26	(see Table 46)
TOTAL	**349**		**349**	

E. General changes in data due to data format updating.

Aerial survey and sighting data from 1979-85 has been similarly formated so that all data can be used for analysis. Each flight was checked and updated into the current format (see Table 1) which often meant changing reason for entry and survey flag data, as well as weather, ice and sea state data. Following are the categories and codes currently used:

reason for entry:

0. FLIGHT ABORTED
1. SIGHT ON TRANSECT
2. SIGHT OFF TRANSECT
3. SIGHT SEARCH SVY
4. START TRANSECT
5. END TRANSECT
6. POSITION UPDATE
7. SONOBUOY DROP
8. RESUME TRANSECT
9. DIVERT TRANSECT

survey flag:

1. ON TRANSECT LEG
2. CONNECTING TRANSECT LEG
3. SEARCH SURVEY
4. BEHAVIORIAL CIRCLING
5. DEADHEAD

weather:

1. CLEAR
2. PARTLY CLOUDY
3. FOG
4. OVERCAST
5. PRECIPITATION
6. LOW CEILING
7. HAZE
8. GLARE

ice coverage: % averaged over one square km

ice type:

0. NO ICE
1. FLOE
2. BROKEN FLOE
3. PACK
4. PACK/FLOE
5. GREASE/NEW
6. SHOREFAST
7. LEAD

sea state:

0. BO. GLASSY, < 1 KNOT
1. B1. LIGHT RIPPLE, 1-3 KTS
2. B2. SMALL WAVES, 4-6 KTS
3. B3. SCATTERED CAPS, 7-10 KTS
4. B4. NUMEROUS CAPS, 11-16 KTS
5. B5. MANY CAPS, 17-21 KTS
6. B6. ALL CAPS, 22-27 KTS
7. B7. BREAKING WAVES, 28-33 KTS
8. B8. FOAM, 34-40 KTS
9. NA. NOT APPLICABLE

Water depths for all sightings 1979-85 have also been updated by means of an automated depth analysis computer program (DEPTH) for the Beaufort, Chukchi and Bering Seas.

Species sighting data from past years changed as all data was updated to the current format. The following are all the categories pertaining to species sightings and, where applicable, the codes used while recording certain variables.

sighting cue:

0. NO CUE: SKIP
1. SPLASH
2. BLOW
3. BODY
4. ICE TRACKS
5. MUD PLUMES
6. BIRDS OR FISH
7. KILL SIGHT
8. OIL SIGHT

behavior:

0. NONE
1. DIVE
2. REST
3. SWIM
4. MATE
5. FEED
6. MILL
7. SPY HOP
8. BREACH
9. ROLL
10. SLAP
11. UNDERWATER BLOW
12. COW/CALF
13. DEAD

total:

size:

0. UNKNOWN
1. CALF OF YEAR
2. IMMATURE
3. ADULT
4. LARGE ADULT

calf number seen:

swim direction (°magnetic):

speed (kts):

0. UNKNOWN
1. STILL 0 KTS
2. SLOW <1 KT
3. MEDIUM 1-3 KTS
4. FAST >3 KTS

aircraft response:

1. = YES
2. = NO
3. = UNKNOWN

repeat sighting:

1. = YES
2. = NO

photo roll number:

photo frames shot:

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APPENDIX E

ENDANGERED WHALE AERIAL SURVEYS IN THE NAVARIN BASIN AND ST. MATTHEW HALL PLANNING AREAS, ALASKA

Donald K. Ljungblad

EXECUTIVE SUMMARY

Support for aerial surveys of endangered whales in the Navarin Basin and St. Matthew Hall Planning Areas was provided to the Minerals Management Service during July 1985 and January 1986 by Navy P-3 Orion aircraft based at Adak, Alaska. Summer surveys conflicted with other Navy priorities, so only one flight was completed and no sightings were made. During the winter period, the Navy provided dedicated aircraft support and five flights were completed, accounting for approximately 50 flight hours. The surveys covered areas from 58°00'N to 63°00'N and from 168°00'W to 177°30'W. Most of the survey effort took place within the westernmost sections of the St. Matthew Hall planning area, adjacent to the Navarin Basin, because most of the Navarin Basin was open water and unsurveyable due to high winds and resultant high sea states. The ice edge was located just north of St. Matthew Island and in this marginal ice zone (10 to 90 percent coverage), weather conditions were generally acceptable for surveys as the presence of the ice kept sea states down.

Thirty-eight bowheads were located within the marginal ice zone, in ice conditions ranging from 10 to 90 percent coverage. Most bowheads seen were resting or swimming slowly in leads or polynas within the marginal ice edge. Little or no water disturbance was evident during all sightings, including a group of five whales that appeared to be mating. These whales were suspended in the water column just below the surface. The lack of water disturbance may have been due to reduced activity by the whales or may have been an artifact of the poor sighting conditions due to reduced light conditions. Other marine mammals seen were belukhas, walrus and bearded seals.

Sonobuoys were used throughout the surveys and provided useful acoustic information on the presence or absence of marine mammals. Sonobuoys dropped in ice-free regions transmitted only loud ambient sea noise. Buoys dropped within the marginal ice zone sometimes provided acoustic evidence that bowhead whales were present.

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INTRODUCTION

Naval Ocean Systems Center (NOSC), San Diego, California has been funded by the Alaska Outer Continental Shelf (OCS) area office of the Minerals Management Service (MMS), U.S. Department of the Interior, since 1979 to conduct aerial surveys of endangered whales and other marine mammals in the northern Bering, eastern Chukchi and Alaskan Beaufort Seas. As part of its responsibilities under the OCS Lands Act, National Environmental Policy Act, Marine Mammal Protection Act, and Endangered Species Act, MMS has continued this work as an extension of previous studies by NOSC. Results of NOSC studies have provided useful information to MMS for preparing environmental impact statements with respect to endangered marine mammals and in making decisions relative to leasing, exploration, and development of the Alaskan OCS.

The MMS expressed a desire to obtain information on the seasonal abundance of endangered whales and other marine mammals in the Navarin Basin of Alaska; however, because of the logistic difficulties in conducting surveys in this area little work has been done. NOSC, in consultation with the U.S. Navy, determined that aerial surveys in support of the MMS objectives for the Navarin Basin can be conducted with the use of the Navy P-3 Orion aircraft operated from the Naval Air Station on Adak Island, Alaska. This report summarizes the results of these surveys.

The Navarin Basin is part of the southern Bering Sea extending from 58°N to 63°N latitude, and from the US-USSR 1867 convention line (International Date Line, IDL) east to 174°W longitude. It is roughly 555 km from north to south and approximately 510 km from east to west, with an area of 141,000 km^2. Approximately 60% of this area, encompassing its northern and eastern portions, lies over the continental shelf, with water depths of about 40 m to 200 m. The southwestern portion of the basin extends into the Aleutian Basin where water depths exceed 3,000 m. These two portions are separated by the continental shelf slope, with depths ranging from 200 m to 3,000 m over distances ranging from 20 to 160 km. Portions of the Navarin Basin were recently released for oil and gas exploration and development, and other portions are scheduled for future leases, therefore information on the seasonal abundance, distribution, and use of this area by marine mammals is highly desirable. Adjacent to the Navarin Basin is a portion

of the St. Matthew-Hall area, which lies between 59°N to 63°N latitude and 171°W to 174°W longitude, and includes St. Matthew Island at its center. This area lies entirely over the continental shelf with depths averaging 200 m. South of the St. Matthew-Hall area lies a portion of the St. George Basin between 58°N and 59°N from 171°W to 174°W. This area also is best described as continental shelf waters with depths averaging 200 m.

Because of its distance from the Alaskan mainland and its extreme and unpredictable weather, few substantial studies of marine mammals have been conducted in the Navarin Basin. Information on marine mammal distribution in the central and western Bering Sea has resulted mostly from Japanese and Soviet whaling cruises (Aldrich, 1889; Cook, 1926; Townsend, 1935; Tomilin, 1957; Berzin and Rovinin, 1966; Nasu, 1974; Nishiwaki, 1984; Wada, 1981); however, none of these data are quantitative and few refer specifically to the Navarin Basin. Post-whaling information on marine mammals has come from the National Marine Fisheries Service's (NMFS) "Platforms of Opportunity Program" (Consiglieri and Bouchet, 1981).

Most recently, dedicated studies of whales and other marine mammals were conducted in the Southern Bering Sea by Brueggeman (1982) and Brueggeman et al. (1984). They utilized vessel and vessel-based helicopter surveys to estimate whale abundance and distribution in the Navarin Basin. Despite the limited coverage owing to the logistics of the vessel and helicopter, these surveys provide the first systematic data on the seasonal occurrence of marine mammals in the Navarin Basin. Their findings suggest that the Navarin Basin is a feeding area for at least gray (Eschrichtius robustus), fin (Balaenoptera physalus), and possibly North Pacific right whales (Eubalaena glacialis) during the summer, and a wintering area for bowhead whales (Balaena mysticetus) and possibly fin whales.

Aerial surveys from fixed-wing aircraft provide a method for determining marine mammal species identification, numbers, and distributions over wide areas in a relatively short period of time, and are often the only practical and safe method of obtaining such information in a large and remote area like the Navarin Basin. Because of its remoteness and notorious weather, any survey effort in this region requires long-duration flights from a suitable base of operation, with alternate airstrips should the weather prevent a return to the base. The lack of availability of suitable aircraft has severely limited efforts to evaluate marine mammal use of the Navarin Basin. Most conventional aerial surveys in

Alaska have been conducted with small twin-engine fixed-wing aircraft (twin otter, twin goose, etc.). None of these aircraft have the endurance to safely conduct long-duration surveys over an area as remote as the Navarin Basin with sufficient reserve fuel to return safely to an alternate base. The U.S. Navy, however, operates aircraft which routinely fly extended surveys over the remote southern Bering Sea. The Lockheed P-3 Orion aircraft is an all weather aircraft utilized on a year-round basis to fly antisubmarine, search and rescue, and marine surveillance patrols from the Naval Air Station at Adak Island, Alaska. This aircraft has an endurance in excess of 12 hours and, therefore, is able to safely reach alternate airstrips should the need arise.

Objectives

The NOSC in San Diego obtained authorization from the Navy to utilize their P-3 aircraft based at Adak, Alaska, under the constraints that the survey would not interfere with ongoing naval air operations. Aerial surveys of endangered whales and other marine mammals during June-July 1985 and January 1986 were part of an interagency agreement between the U.S. Navy and the U.S. Department of the Interior (MMS). The specific objectives of this research were to:

1. assess the seasonal habitat use of the Navarin and western portion of the St. Matthew-Hall and St. George Basins by cetaceans, as possible, by determining the minimum seasonal abundance, distribution, and relationship to environmental parameters of endangered cetaceans, in particular the bowhead whale,
2. document the distribution of all other species of marine mammals observed during these surveys and provide minimum estimates of abundance,
3. record waterborne sounds of endangered cetaceans, ambient and industrial noise to provide a baseline of acoustical data from this area for comparison with equivalent information from other shelf regions currently with and without industrial activity, and
4. use the information from objectives 1-3 to expand knowledge of the seasonal relationship of endangered whales, particularly the bowhead whale, to environmental and oceanographic conditions, such as ice, with the long-term aim of developing remote sensing capability to evaluate the seasonal populations of all endangered whales in the Navarin and western portion of the St. Matthew-Hall Basin.

Background

The seasonal climate of the Navarin Basin and western St. Matthew-Hall area has been thoroughly reviewed by Brower et al. (1977), Gusey (1983), and Brueggeman et al. (1984), and only specific features relevant to the aerial surveys conducted are presented below.

Typically cold temperatures, high wind speeds, and extreme ranges in day length promote the seasonal development of sea ice in the Navarin Basin (Brower et al., 1977). Brueggeman et al. (1984) state that "Average annual air temperatures and wind speed are 0° C and 14 knots year long, and visibility less than 2 nm persists approximately 14% of the year. Temperatures are coldest during the early spring when wind velocities are lowest. Wind velocities exceeding 20 knots are most frequent in the fall when visibility is poorest; the best visibility conditions occur in the winter but day length is less than 6 hours."

Regarding the seasonal occurrence of sea ice in the study area, Brueggeman et al. (1984) state "Sea ice persists in the Navarin Basin from December throughout June. Ice coverage of the Basin is greatest from February through April. It (ice) seldom extends south of the outer continental shelf and is typically less than 1 m thick. Breakup of the sea ice begins in mid-April, and the Basin is generally ice-free by late June. The combination of sea ice, harsh environmental conditions, and remoteness demonstrate the difficulties of surveying for marine mammals in the Navarin Basin."

Target Species

Marine mammal species reported from the southern Bering Sea include members of three families of pinnipeds (Otariidae, Odobenidae, and Phocidae), and eighteen species of mysticete and odontocete cetaceans.

The cetaceans for which some documentation of occurrence in the southern Bering Sea and possibly the Navarin Basin exists include:

*Fin Whale (<u>Balaenoptera</u> <u>physalus</u>)
*Humpback Whale (<u>Megaptera</u> <u>novaeangliae</u>)
*Gray Whale (<u>Eschrichtius</u> <u>robustus</u>)
*Pacific Right Whale (<u>Eubalaena</u> <u>glacialis</u>)
*Bowhead Whale (<u>Balaena</u> <u>mysticetus</u>)
*Sperm Whale (<u>Physeter</u> <u>macrocephalus</u>)
Minke Whale (<u>Balaenoptera</u> <u>acutorostrata</u>)

Bering Sea Beaked Whale (Mesoplodon stejnegeri)
Baird's Beaked Whale (Berardius bairdii)
Goose-beaked Whale (Ziphius cavirostris)
Northern Right Whale Dolphin (Lissodelphis borealis)
Killer Whale (Orcinus orca)
Harbor Porpoise (Phocoena phocoena)
Dall's Porpoise (Phocoenoides dalli)
Belukha Whale (Delphinapterus leucas)
* = **Endangered**

Although most of these species are believed to range in ice-free waters, many may move northward across the Bering Sea and through the Bering Strait into the Chukchi Sea to feed on seasonally abundant prey which are found in these waters. Two species that are commonly known to be associated with seasonal sea ice are the belukha and bowhead whales. In spring both these whales penetrate the ice floes nearly 3,000 km by following faults and leads. Their wintertime distribution is assumed to be associated with the ice edge, but it has yet to be adequately described. The Western Arctic stock of bowhead whales is the primary interest of this study. This population moves seasonally between the Bering, Chukchi, Beaufort, and (to a limited degree) Eastern Siberian Seas.

Alaskan and Siberian aboriginal whalers have hunted bowheads for more than a millenium (Marquette and Bockstoce, 1980). The size of the stock just prior to 1848, when its exploitation by Yankee pelagic whalers began, has been estimated as 14,000 to 20,000 individuals; it is thought more likely to have been near the upper end of that range (Bannister, 1984). American commercial whalers killed an estimated minimum of 18,658 animals between 1848 and 1915 (Bockstoce and Botkin, 1983). Whaling by Eskimos for subsistence has continued since 1915, and this activity is at the center of an international controversy concerning the stock's chances of survival and recovery (Mitchell and Reeves, 1980; Donovan, 1982; Gambell, 1983). In recent years this controversy has broadened to include concern about the effects of oil and gas resource development on the whale population and its ecosystem.

The Western Arctic stock was estimated to contain 3,817 individuals in 1983 (Zeh et al., 1983; Bannister, 1984). There have been definite removals of 8 to 17 whales per year from 1978 to 1983, and additional strikes of 6 to 18 whales per year during this time, resulting in some unknown amount of additional mortality.

Townsend (1935) plotted positions, by month, of 5,114 bowhead kills in the Sea of Okhotsk and the Bering, Chukchi, and Beaufort seas, from latitudes 53°N to 73°N and longitudes 120°W to 135°E. Townsend's charts, however, may not be completely trustworthy. In particular, entries in 18th Century whaling logbooks and journals, such as those used by Townsend as his primary sources of data, are not always clear in distinguishing bowheads from right whales (Reeves and Mitchell, in press; Bockstoce and Botkin, 1983).

There is no information available on distribution of bowheads in the study area for the first seven decades of this century. Recent sightings include five reports of sightings of bowheads in the southeast Bering Sea. Braham et al. (1977) plotted locations of three sightings in "early spring" between about latitude 55°33'N and 57°40'N near longitude 164°W. Braham et al. (1982) also reported a sighting made "just west of St. Paul Island in April 1976". Details of these records, including identity of observers and probable reliability of identifications, were not presented.

In the Navarin Basin Synthesis report (see Science Applications Inc. (SAI), 1981, Figure 9.1) there are nine symbols indicating sightings of bowheads at unstated seasons. These records are attributed to "NMFS, unpublished data".

Brueggeman (1982) (also published previously as Braham et al., 1980) reported 64 bowheads in a 55 x 59 km study block just west of St. Matthew Island during aerial surveys there in early April 1979. Those sightings were used to support his estimate of 119 whales for the block. Surveys in March and April in 15 other widespread study blocks, seven of them along the pack-ice edge in the mid-Bering Sea and nine south and west of St. Lawrence Island, produced sightings and estimates of only 45 and 57 whales respectively. Therefore, 60% of all bowheads seen and 68% of those estimated to have been in the study blocks during Brueggeman's surveys were near St. Matthew Island. Thirty-nine percent of the whales sighted (and 31% of the whales estimated) were near St. Lawrence Island. Only one of the bowhead sightings was along the pack-ice edge in the central Bering Sea.

On ship-based aerial surveys of the Navarin Basin in February and March 1983, observers saw bowhead whales only near St. Matthew Island, where an estimated total of 25 individuals (no duplicates) were reported for one study block (Brueggeman, 1984).

The winter distribution of the remnant Bering Sea stock of bowhead whales and the relative importance to them of the southeast Bering Sea remains problematic. It has often been stated that bowheads winter principally in the pack ice south and west of St. Lawrence Island and that they also range southward to St. Matthew Island and perhaps westward along the ice edge from the Pribilof Islands to the coast of the U.S.S.R (Braham et al., 1980; Braham et al., 1982; Morris, 1981). The "known" winter range has been extrapolated from rather scant evidence to include a major portion of the central Bering Sea north of latitude 57°N but not to extend farther southeast than about St. Matthew Island (Morris, 1981: Fig. 5.5). Such conclusions are apparently based on past whaling records (Townsend, 1935; Cook, 1926) and on observations by Alaskan Eskimos (Braham et al., 1980). Available data on present distribution (presented in Brueggeman, 1982), can as easily be construed to indicate that in winter (February and March) the whales are more abundant near St. Matthew Island than elsewhere and that the concentrations observed near St. Lawrence Island during the whaling season of March through May (Marquette, 1977; 1979; Marquette and Bockstoce, 1980) reflect a movement of the population to the polynyas near Southwest Cape anticipating the northward migration. There are no data on the mid-winter distribution of the species in other areas east of the USA/USSR convention line, and the data for that period closest to mid-winter (Feb-Mar) support the hypothesis that substantial numbers of bowheads winter near St. Matthew Island. At the very least it appears, as postulated by Brueggeman (1982), that the open water areas around St. Matthew Island serve as a staging ground where whales from the southern ice front congregate to await the opening of a lead to open waters near St. Lawrence Island.

Hanna (1920) noted that the bones of this species, including some whole and some partial skeletons along the drift line and some bones half-buried in the tundra far back of the high tide mark, were abundant on all beaches of St. Matthew Island. If these identifications were correct such records provide evidence of the species' historic presence in the area.

Concerning present penetration of bowheads farther than St. Matthew Island, there are only the sightings discussed above. To the extent that bowheads depend on the ice front and negotiable pack-ice regions for suitable habitat (Eschricht and Reinhardt, 1866), their distance of penetration into the southeast Bering Sea in any given year and their use of any specific area will be related to the maximum extent of ice advance (Potocsky, 1975). It is not yet clear whether bowhead whales feed during winter (Lowry et al., 1982), nor is it clear what role ice plays in their behavior and natural history (for example, as sanctuary from bad weather and killer whales). Therefore, until more is known about the species, there is little basis for speculating about the importance of the present study area to bowheads or about the effects that destruction or modification by industry of the ice and substrate might have on their survival.

METHODS

Survey Rationale

In 1981 and 1982 limited systematic vessel and vessel-based helicopter surveys were conducted in the Navarin Basin by Brueggeman et al. (1984). These surveys included approximately 54.8 hours of helicopter effort. In consultation with MMS, it was determined that the initial P-3 surveys would be most useful if they complemented the Brueggeman et al. (1984) surveys with respect to areas covered and season of survey. It was decided by MMS that, whenever possible, the first priority for the P-3 surveys would be to include areas not previously surveyed by Brueggeman et al. (1984), then to provide replicate surveys for comparison of the same areas in different years.

Brueggeman et al. (1984) divided the study area into three zones, each with a characteristic submarine topography which may correlate with the distributions of marine mammals. These zones are (1) the shallow water zone or the outer continental shelf, (2) the transition zone corresponding to the area between approximately 10 km northeast of the 200 m contour line and 10 km southwest of the 3,000 m contour line, and (3) the deep water zone with depths >3,000 m. The MMS divided the study area into 14 sections or blocks, each one degree in latitude long by 3 degrees longitude wide except for those bordering the IDL, which were smaller (Figure E-1). The nine westernmost sections (NP1-4 to NP1-8; NO1-1 to NO1-4) comprise the Navarin Basin Lease Area. The remaining five sections (A-E) are part of the St. Matthew Hall Lease Area (A-D) and St. George Basin Lease Area (E). Blocks NP1-5, NP1-7, N01-1, N01-3, and N01-4 comprise combinations of all three depth zones while the remaining 9 blocks represent outer continental shelf water only.

Summer Surveys

Brueggeman et al. (1984) conducted 3958 km of systematic vessel and vessel-based helicopter surveys in the Navarin Basin between 11 May and 10 June, 74% (approximately 16 hours) of which were conducted by helicopter. A second series of surveys were conducted between 20 July and 19 August and comprised 2568 km of survey line, 71% (approximately 9.8 hours) of which were conducted by

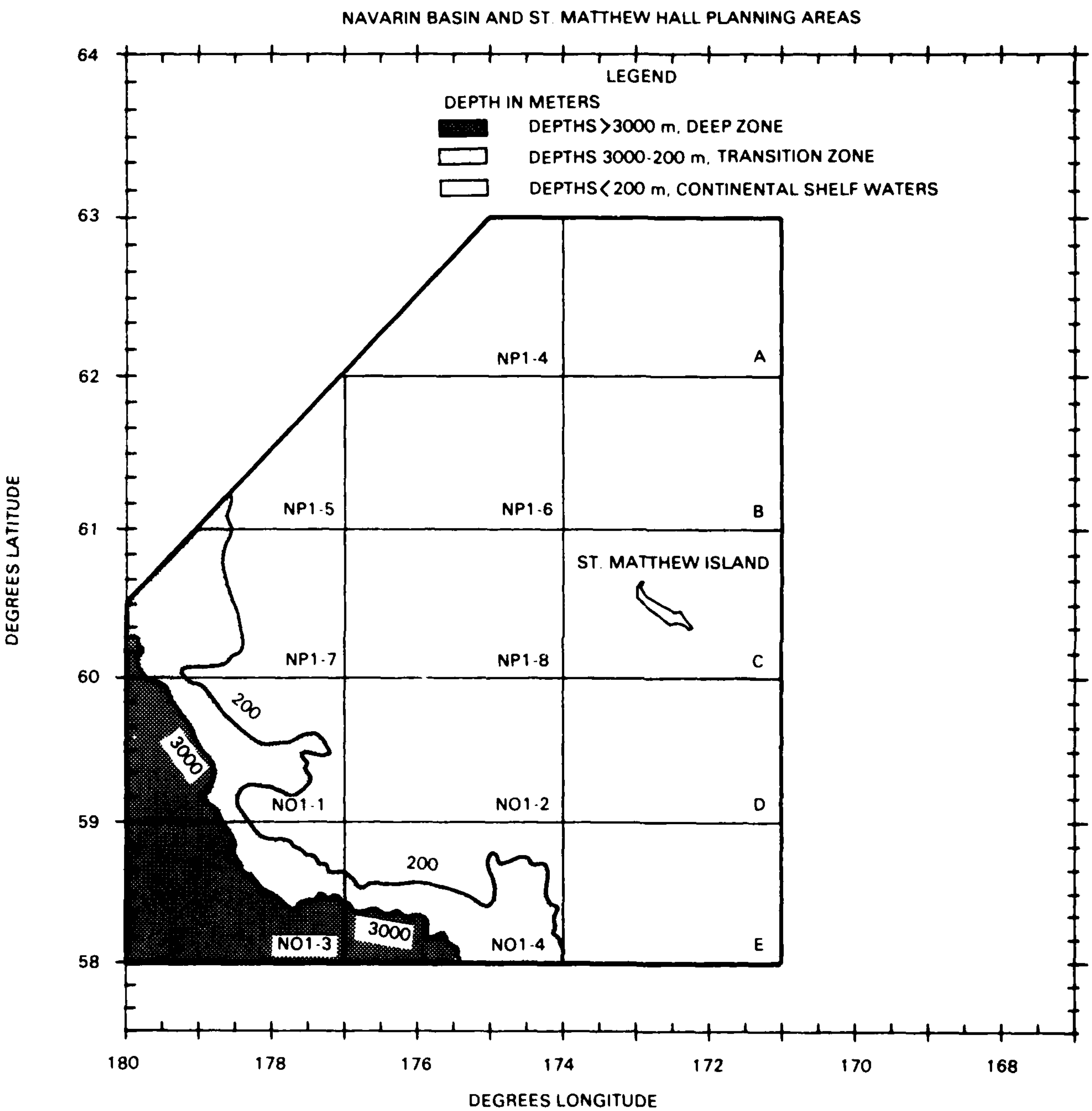

Figure E-1. Navarin Basin study area.

helicopter. Brueggeman et al. (1984) effort was concentrated between 59°40'N to 61°20'N and 173°30'W to 179°W (Figure E-2). The majority of their whale sightings were in shallow outer continental shelf waters where marine mammal species diversity was also the highest.

To complement this effort, the P-3 summer surveys were planned for 10 June to 20 July 1985. With regard to lack of previous coverage and greatest expected abundance of marine mammals, the areas with the highest priority for surveys included the northwestern portion of block NP1-4, all but the southernmost portions of NP1-5 and N01-1, and the northern half of N01-4. These areas comprise mostly shelf waters, where the greatest abundance of endangered whales were previously reported. The remaining areas had received complete or partial coverage by Brueggeman et al. (1984) or comprise deep water zones where marine mammal abundance is expected to be low, and thus were second priority for summer surveys. MMS did not express an interest in summer surveys of blocks A-E therefore, these blocks were not included in the planned summer 1985 survey effort.

Winter Surveys

Brueggeman et al. (1984) winter effort included 2,495 km of systematic vessel and vessel-based helicopter surveys of the Navarin Basin between 29 October and 12 November, 99% (approximately 13 hours) of which were conducted by helicopter. Another series of winter surveys were conducted along the marginal ice front between 19 February and 18 March and included 4,468 km of track line, 68% (approximately 16 hours) of which were flown by helicopter. The Brueggeman et al. (1984) effort was concentrated between 59° to 61°20'N and west of St. Matthew Island to approximately 179°W (Figure E-3). All of this area is over the outer continental shelf and thus it may be classified as shallow water zone with the highest probability for marine mammal sightings. Only one series of transects was conducted over transitional water in the southern half of block N01-4, and another series in the northernmost blocks of NP1-4 and A. Due to the anticipated ice coverage of the northern portion of the study area in winter, MMS requested that all winter P-3 surveys be flown below 61°N latitude, thereby eliminating blocks (NP1-4, NP1-5, NP1-6, A and B) unless weather satellite imagery indicated the presence of polynyas, faults, or leads of sufficient size to warrant investigation.

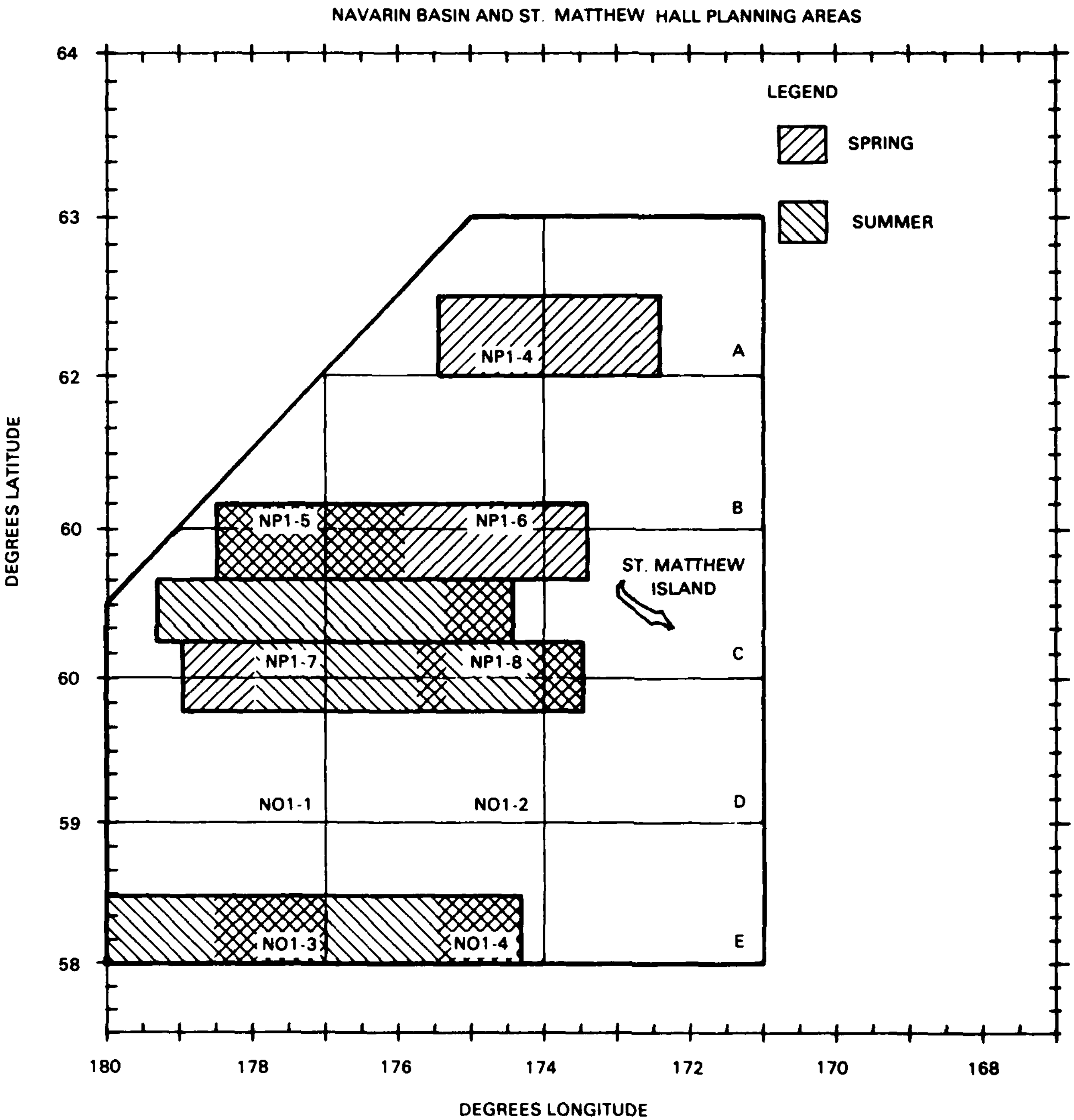

Figure E-2. Brueggeman et al. (1984) survey coverage: spring and summer.

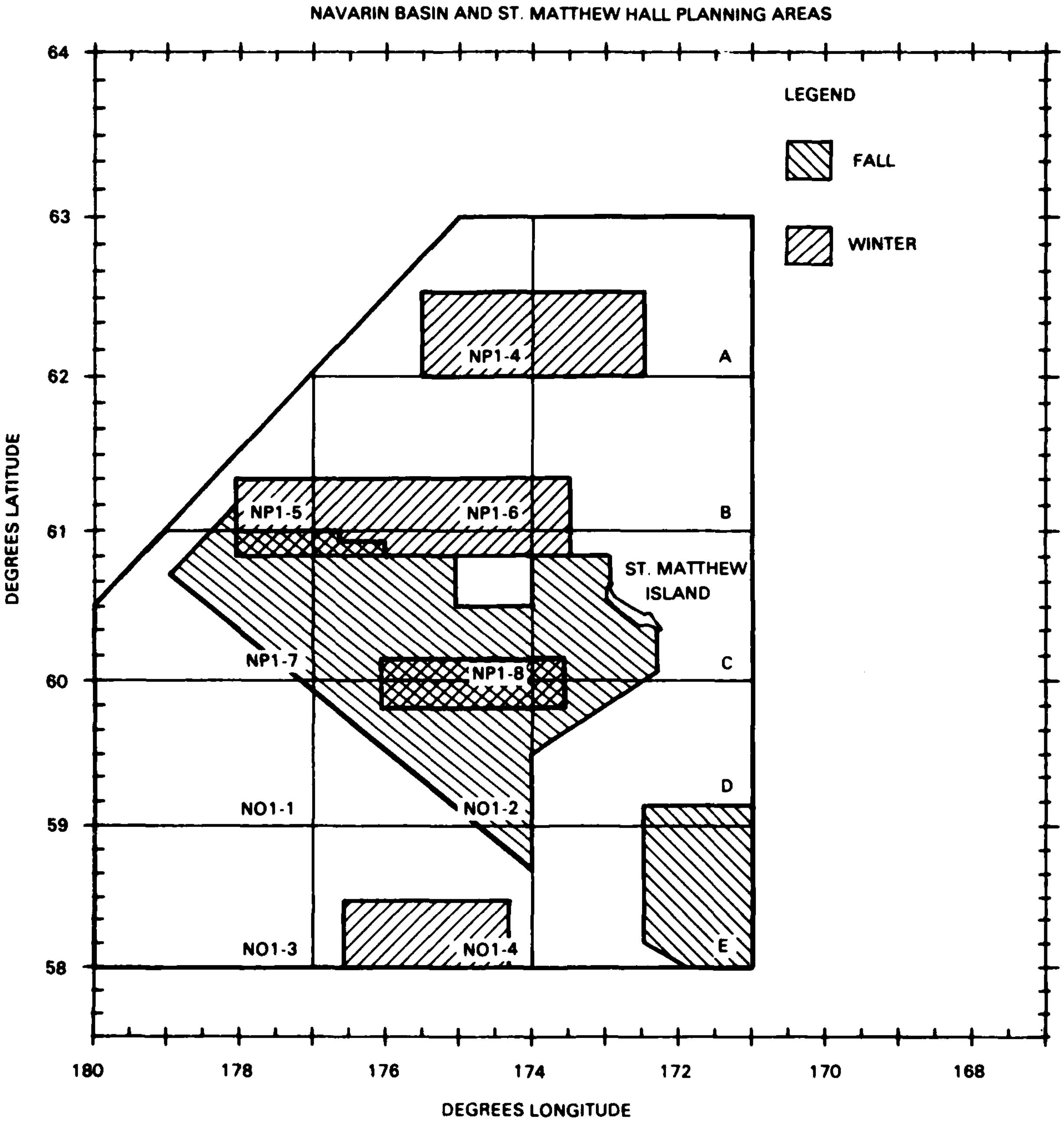

Figure E-3. Brueggeman et al. (1984) survey coverage: fall and winter.

The winter P-3 surveys were to begin in late January when sufficient daylight would be available to complete a survey. To complement the Brueggeman et al. (1984) coverage (Figure E-3), P-3 winter surveys were planned for block C east of St. Matthew Island, most of block D, the western half of block E, the eastern shelf portion of block N01-1, the southwestern portion of N01-2, and the northern half of block N01-4. Second priority flights included surveys of areas previously surveyed by Brueggeman et al. and areas over the transitional and deep water zones below 61°N.

Transect Procedure

Because endangered cetaceans (large whales) are the main focus of these surveys, strip transects (Eberhardt et al., 1979) were flown through areas to be surveyed within each block to estimate relative density, abundance, and distribution of cetaceans. When transects are utilized to estimate densities and numbers of animals present in an area, the locations of each transect line should be randomized within the study site (Caughley, 1977; Cochran, 1977; Eberhardt, 1978). To establish the placement of transect lines in areas of open water, each block was divided into segments running north-to-south. Random numbers were drawn to assign the starting, termination, and/or turning points for each transect line, which were then alternately connected at the ends of each segment so that no two lines cross. Transect strip width was defined as 0.92 km (0.50 nm) visible on each side of the aircraft track line (not including the blind spot under the plane) for a combined strip width of 1.852 km (1.00 nm). The number of transect lines was calculated to provide a minimum survey coverage of 10% of each area (Figure E-4). Surveys over ice, particularly in the winter, concentrated as possible in areas with the greatest probability of open water polynyas, faults, and leads, as marine mammals would be expected to congregate in these regions. Weather satellite imagery was consulted on a regular basis to establish the order of priority for surveys over ice.

Aircraft

The P-3 Orion aircraft (Figure E-5) facilitated the surveys of the Navarin and western St. Matthew-Hall Basin. The most important aspect of any aerial survey program is safety, and other aircraft currently available in the private sector that comply with the minimum safety requirements for operation in this region are

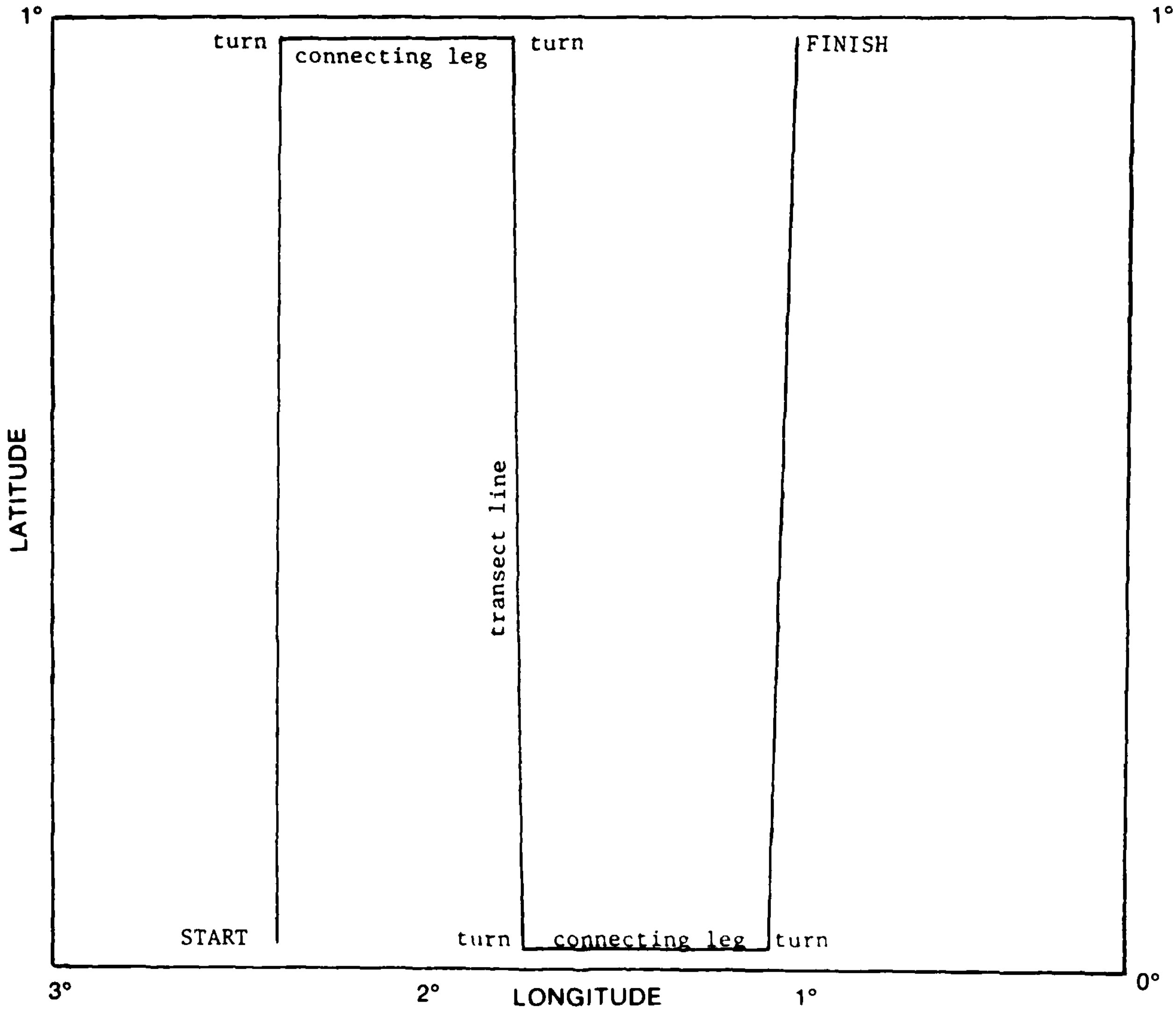

Figure E-4. Example of random transect lines through a survey block in the study area.

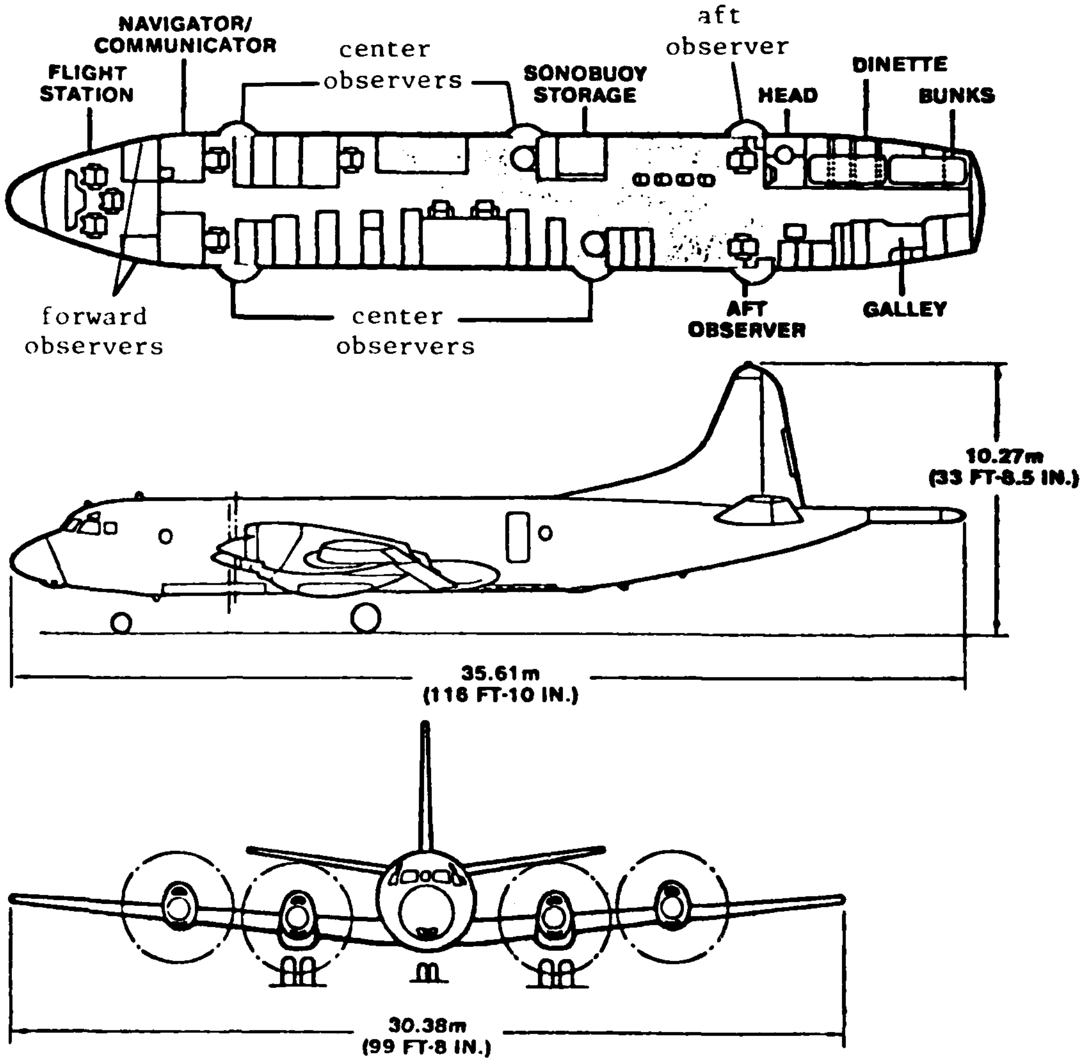

Figure E-5. Schematic diagram of Lockheed P-3 Orion aircraft.

cost prohibitive. Furthermore, the P-3 was a suitable aircraft to carry out the objectives of the program. Because it was designed as a long-distance surveillance aircraft, the P-3 combines safety with full performance capabilities better than any other available aircraft.

The P-3 is a four-engined (turboprop) aircraft with a maximum flight endurance in excess of 12 hours. Normal cruising speed was 300 knots, thereby minimizing transit time between base and the study site. Once onsite, cruising speed was reduced to between 170 and 210 knots, depending on fuel load, to perform low altitude surveys.

Aircraft instrumentation included a Navigation System, radar, radar altimeter, infrared camera, 16mm camera, and sonobuoy deployment, receiving and analysis capabilities. Flight track information was recorded in real time by the on-board computer. These records were recorded on paper and on magnetic tapes for later reconstruction of each flight during laboratory analysis.

The aircraft was capable of carrying 12 crew members. Bubble windows were located on each side of the aircraft, both aft and forward of the wings (Figure 5). Complete survival equipment, including survival suits, parachutes, rafts, flares, and food, were carried as standard equipment.

Sighting Procedure

Observers were positioned behind the pilot and co-pilot for forward and downward scanning. The pilots, co-pilots and crew proved extremely useful as ancillary observers. Each observer had a clinometer to take angles on all whale sightings abeam of the aircraft to provide a measure of animal distance from the track line. Binoculars and cameras with telephoto lenses were also available. Standard survey altitude was 305 m or lower dependent on ceilings and survey speed was between 170 to 210 knots.

Flight data were routinely updated and recorded at 10 minute intervals during each flight independent of sighting events. Data recorded included:

Aircraft:

- Position
- Altitude
- Heading
- Air and ground speed, and

Environmental Data:

Through-air visibility (poor, fair, good, excellent)

Beaufort sea state

Surface water temperature

Ice type and coverage

Glare

For each marine mammal sighting, the following data were recorded in addition to the flight information listed above:

Marine Mammal:

Observation Number

Species

Number in group

Vertical angle when animal is perpendicular to aircraft track

Direction traced or orientation at time of sighting

General behavior (when possible)

Reliability of identification (positive ID or questionable)

Data Processing and Quality Control

Data was recorded on hand-held casette recorders and onboard Navy computers. After the survey, flight data from these two sources were integrated and entered on HP-85 desktop computers. The computer software utilized for data processing and quality control of the Navarin Basin information was essentially the same as that used for aerial surveys in the Beaufort Sea in fall.

The distribution of marine mammal sightings are presented as computer-generated maps of the study area with the location of individual sightings and the aircraft tracklines shown.

In response to MMS's long-term aim of correlating the distribution of marine mammals in the Navarin Basin with environmental parameters, the type and location of ice cover, surface water temperature, and weather conditions were routinely recorded.

RESULTS

SUMMER

The summer survey period began 7 June 1985 with survey personnel remaining at Adak through 1 July 1985. An attempted survey on 13 June was aborted shortly after takeoff due to failure of navigation systems. One flight was completed on 14 June, when planning areas N01-1 and N01-3 were surveyed.

Daily Flight Results-Summer

14 June 1985

Flight E-1 was an attempted survey of planning areas N01-2 and N01-4 between 58° - 60°N and 174° - 177°W. Fog and unacceptable visibility rendered it impossible to survey in those areas, and alternate areas N01-1 and N01-3 were surveyed instead. Fog and inclement weather forced the survey of the northern area (N01-1) to be aborted after completion of only three lines (Figure E-6), but coverage of area N01-3 (58° to 59°N and 177°W to 180°W) was complete. Survey conditions in this area were excellent - clear with unlimited visibility and sea state of Beaufort 4 or less. No whales or other marine mammals were seen, although numerous ships, crab pot buoys, and miscellaneous flotsam were spotted. Sonobuoys were dropped and picked up only ambient sea noise and some sounds from industrial ships and drilling vessels that were seen during this flight.

WINTER

The winter surveys were conducted from 23 January through 31 January 1986. During this period 5 surveys were completed (Figure E-7) and one was aborted, accounting for approximately 50 flight hours. Over half (56%, n = 28 hours) of the survey time was spent in transit flights through the southern Bering Sea region. The short daylight hours (less than 6 hours) prevented effective surveying in this area as most transit flights were carried out under limited light conditions. The remaining 22 hours flown were either transect surveys (49%, n = 10.8 hours) in blocks or search surveys (51% n = 11.2 hours). Six percent (n = 1.3 hours) of the survey time was spent in the St. George Basin lease area, 23 percent (n = 5.1 hours) in the Navarin Basin lease area, and 71 percent (n = 15.6 hours) in the St. Matthew Hall Basin lease area. Although surveys south of the ice edge were attempted on nearly every flight, high sea states (>Beaufort 5) and low sightability conditions

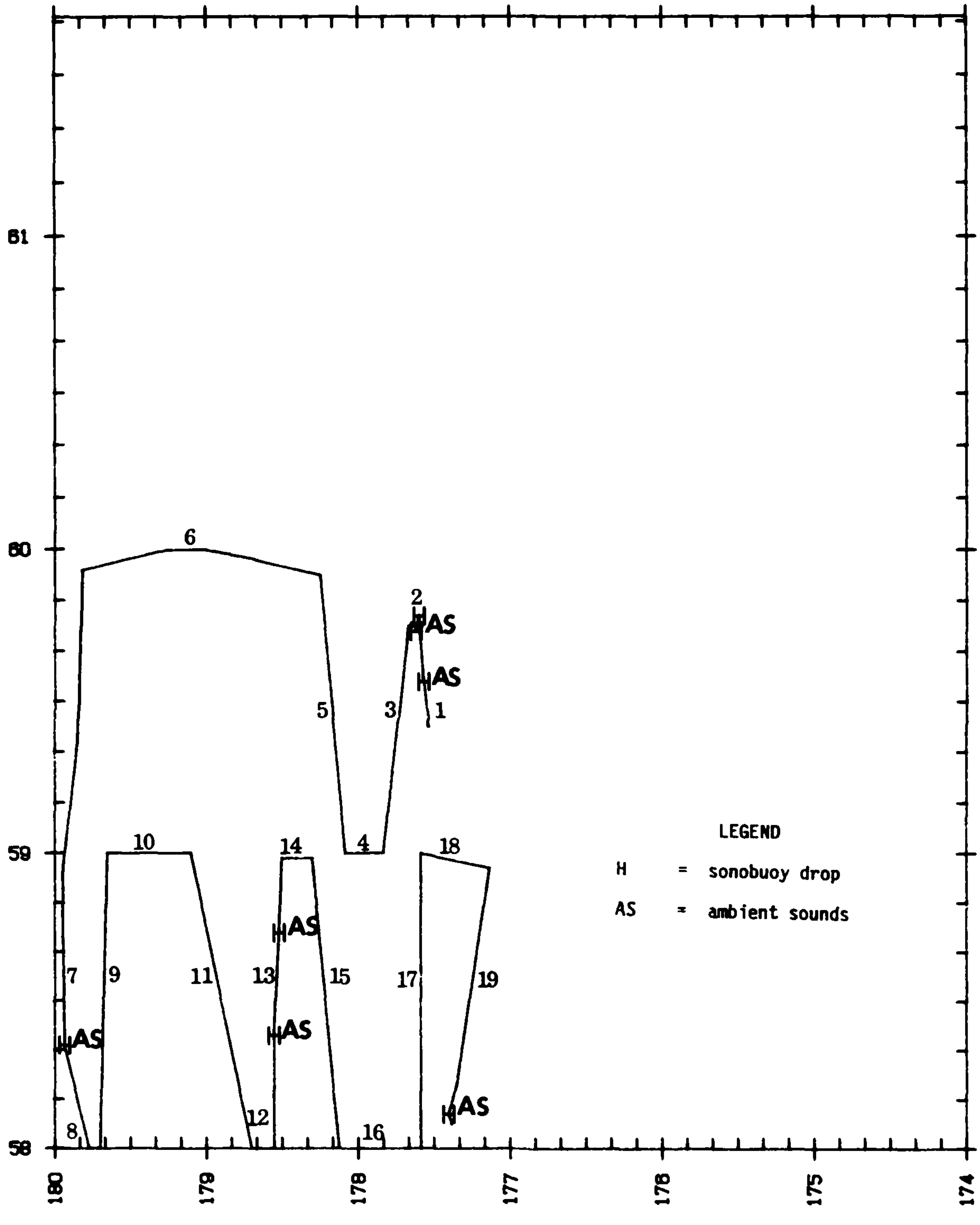

Figure E-6. Flight track for flight E-1, 14 June 1985.

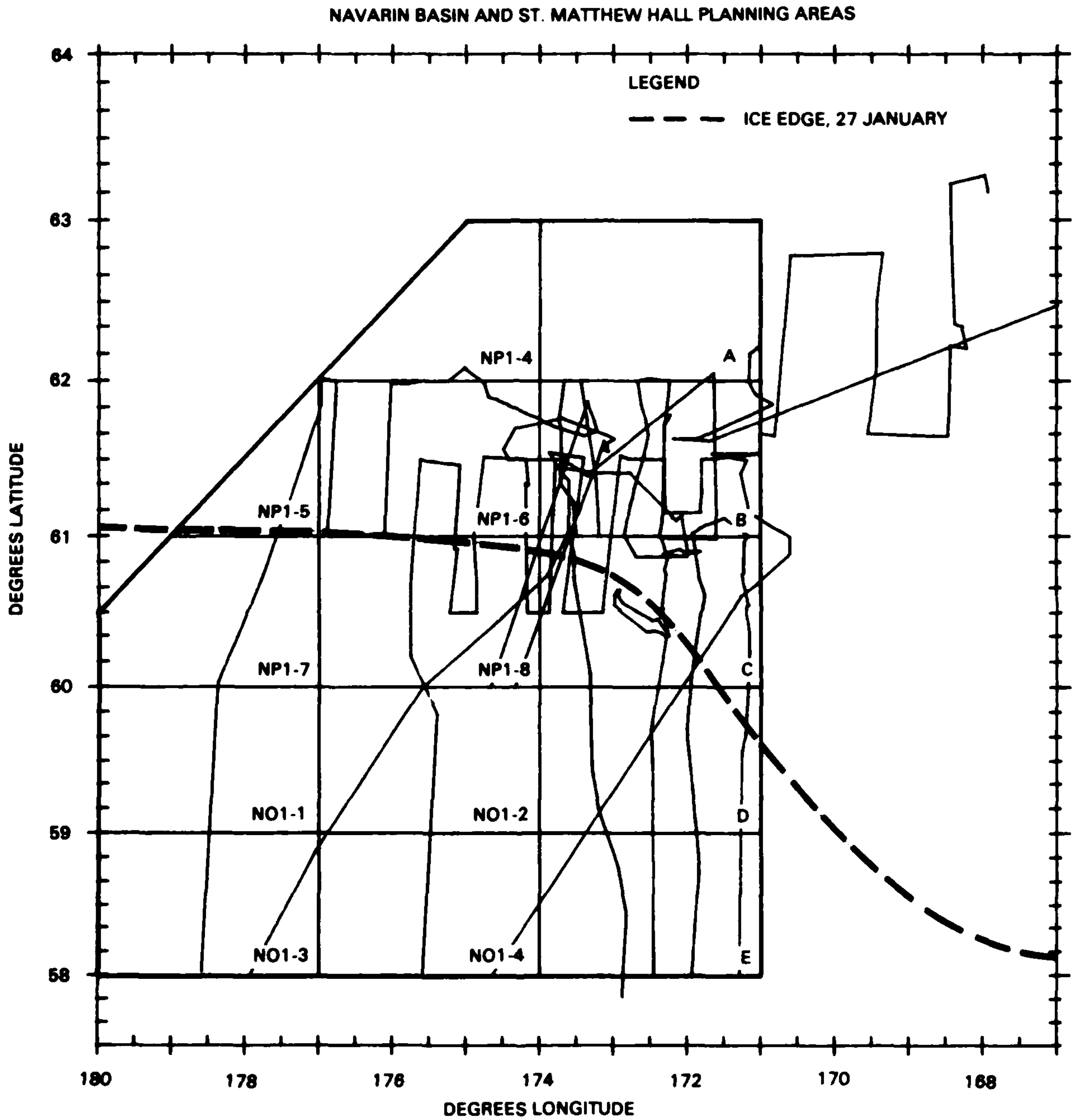

Figure E-7. Combined survey track lines in the Navarin Basin and St. Matthew Hall planning area, 23-31 January, 1986.

precluded surveying these areas. Only in areas with ice coverage $\geq$10 percent were sea states low enough to successfully survey. The marginal ice front (10 to 90 percent coverage) was farther north than usual in January 1986 (Figure E-8), and most areas influenced by ice were in the St. Matthew Hall lease area; therefore, more survey time was spent there.

Sea states in the open water areas south of the ice edge varied from Beaufort 4 to 7, with an average sea state of Beaufort 5 to 6. Visibilities ranged from one km and fog to 10 km with patchy fog and snow squalls. Ceilings were quite restrictive, with levels generally below 152 m (500 ft). The only reasonably good survey conditions were located near and over the marginal ice zone (Figure E-8), where visibilities improved and open water areas were relatively calm (Beaufort $\leq$ 4), even though surface wind conditions were quite high (35 knots).

Eighteen sightings of thirty-eight bowheads were made during the winter surveys (Figure E-9). Five sightings (28%) of eight whales were made while on transect legs. All other sightings were made on connect legs (n = 2, 11%), search legs (n = 10, 56%) or while behavioral circling (n = 1, 5%). Most whales (n = 30, 79%) were seen in $\geq$70 percent ice conditions (Table E-1). No calves were seen. Other marine mammals sighted were belukha whales, walrus and bearded seals (Table E-2).

Daily Flight Results - Winter

23 January 1986

Flight E-2 began at 58°00'N, 171°17'W (Figure E-10: leg 1) proceeding north to 61°00'N 171°10'W. The ice edge, located at 60°13'N, 171°12'N, consisted of 40 percent small pan new ice. One bowhead was sighted on this leg at 60°32'N, 171°12'W, lying stationary in a small polynya next to the ice edge. Ice conditions at this location were 90 percent small broken pan. The whale dived in response to the aircraft, which was at 91 m (300 ft).

A sonobuoy was dropped as the track turned west at 60°58'N, 171°13'W (Figure E-10: leg 2). Ice conditions at this location were 90 percent new ice with occasional small polynyas; this sonobuoy transmitted numerous very loud whale calls. Enroute from this point to the next southern turning point 31 walrus were seen in various groupings.

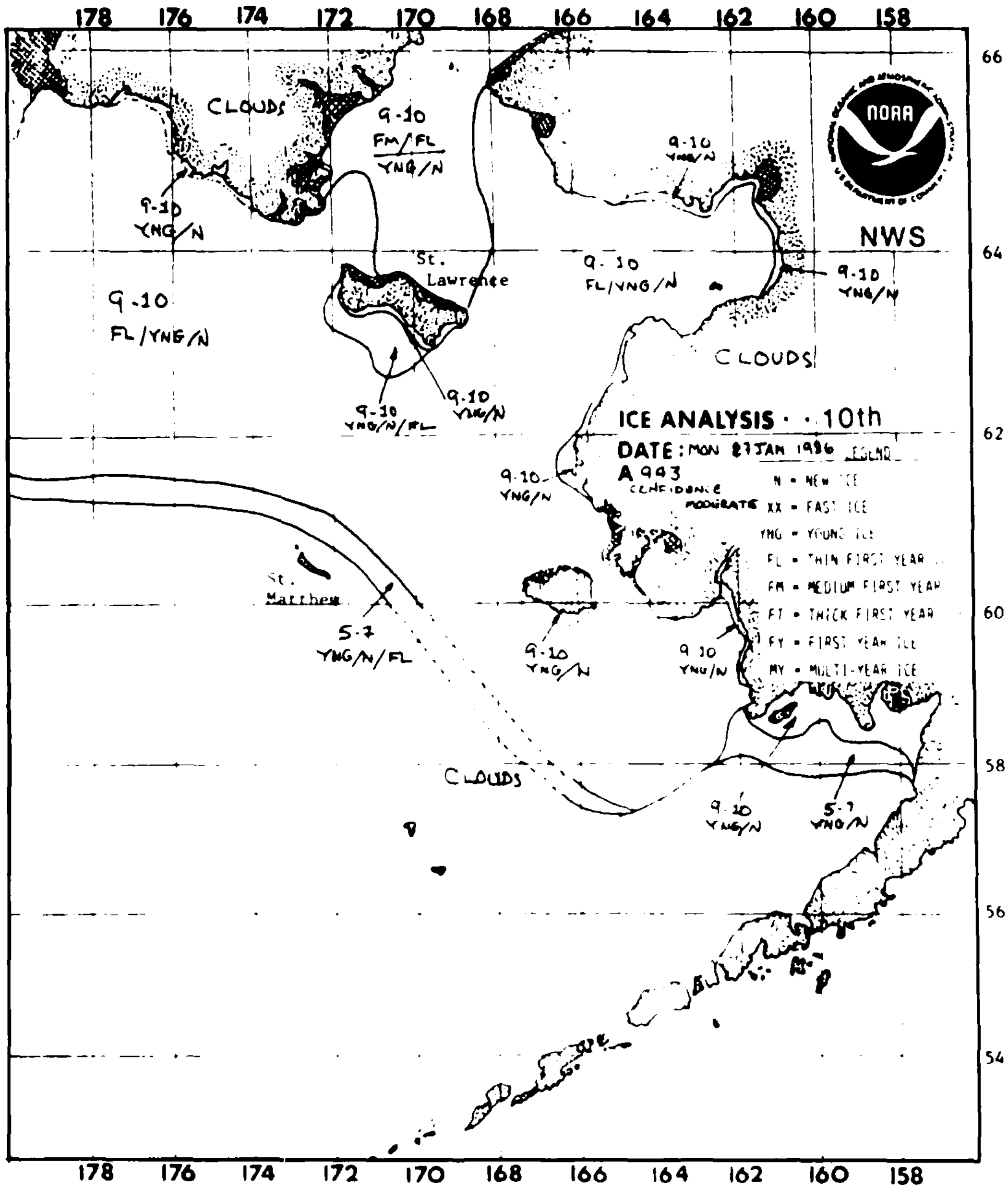

Figure E-8. Ice analysis, 27 January 1986. Data from National Weather Service; Anchorage, AK.

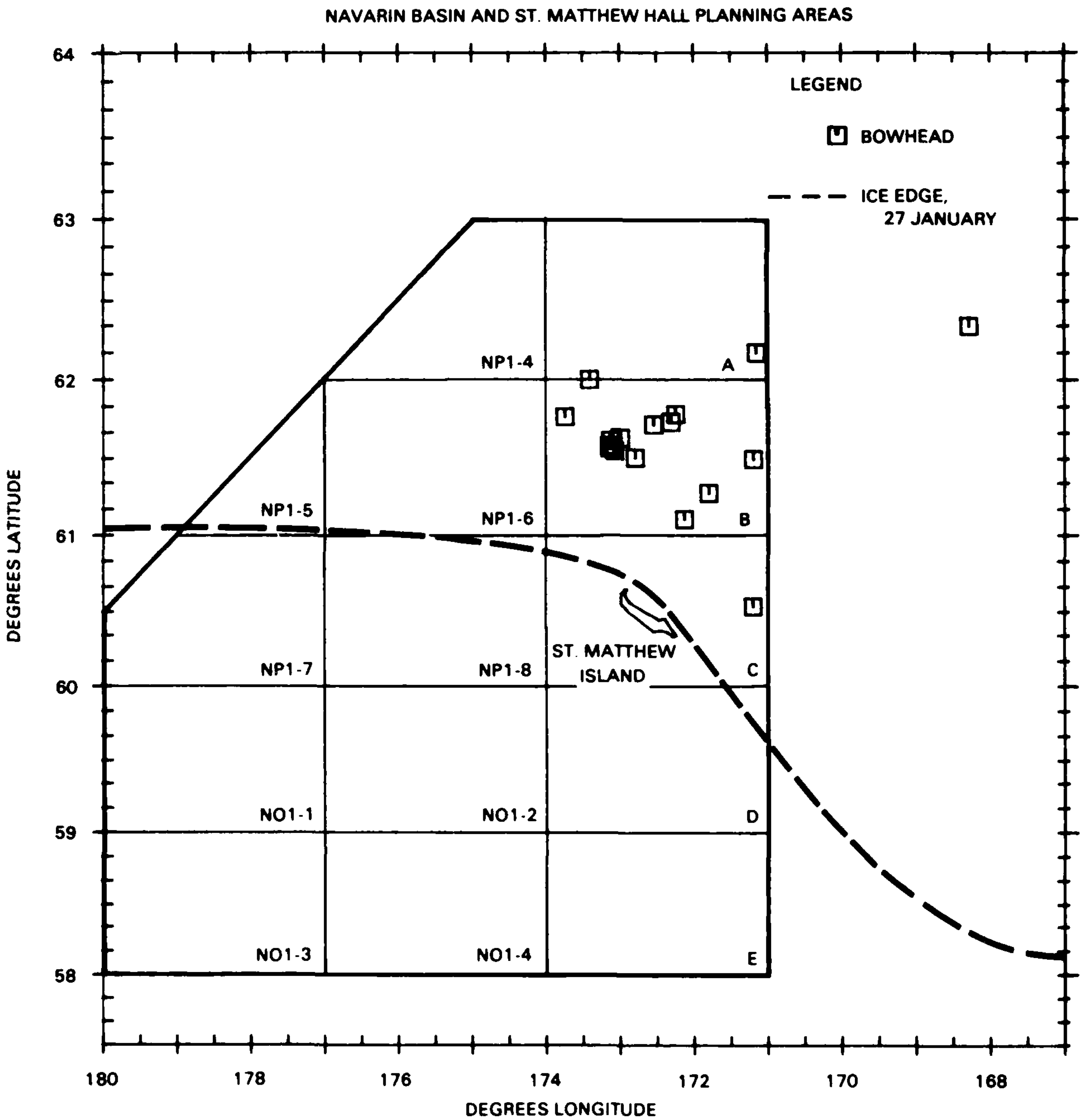

Figure E-9. Distribution of 18 sightings representing 38 bowhead whales in the Navarin Basin and St. Matthew Hall planning area, 23-31 January 1986. Dashed line indicates marginal ice edge, 27 January 1986.

Table E-1. Summary of Bowhead (BH) sightings in the Navarin Basin, January 1986. Dash (-) indicates no data.

Date	Flt. No.	No. BH	Latitude (N)	Longitude (W)	Distance (meters)*	Sighting Cue	Behavior	Heading (magnetic)*	Ice (%)	Ice Type	Sea State
23 Jan	E-2	1	60°32'	171°12'	117	Body	resting	-	90	broken pan	B1
23 Jan	E-2	5	61°06'	172°08	-	Body	mating	-	90	pan	B2
24 Jan	E-3	1	61°29'	172°47'	-	Body	resting	-	90	pan	B5
24 Jan	E-3	1	61°16'	171°48'	220	Body	resting	-	90	floe	B6
24 Jan	E-3	1	61°29'	171°12'	-	Body	resting	-	70	pan	B6
27 Jan	E-4	1	61°46'	173°44'	435	Body	resting	-	40	floe	B3
27 Jan	E-4	2	62°00'	173°24'	-	Body	resting	-	70	pan	B2
27 Jan	E-4	4	61°43'	172°32'	-	Body	swimming	300	50	pan	B2
27 Jan	E-4	1	61°44'	172°18'	-	Body	resting	-	60	floe	B2
27 Jan	E-4	1	61°47'	172°14'	-	Body	swimming	170	70	pan	B2
27 Jan	E-4	1	61°38'	172°59'	-	Body	resting	-	10	pan	B3
27 Jan	E-4	2	61°35'	173°08'	-	Body	resting	-	70	pan	B2
27 Jan	E-4	6	61°35'	173°05'	-	Body	resting	-	70	pan	B2
27 Jan	E-4	6	61°34'	173°08'	-	Body	resting	-	70	grease	B2
27 Jan	E-4	1	61°33'	173°04'	-	Body	resting	-	70	pan	B2
27 Jan	E-4	1	61°37'	173°07'	-	Body	resting	-	70	pan	B2
31 Jan	E-6	2	62°20'	168°17'	-	Body	resting	-	90	floe	B1
31 Jan	E-6	1	62°10'	171°09'	-	Body	resting	-	90	pan	B1

*Data on distance of sightings from trackline and whale headings were difficult to obtain as whales were usually seen for a very short time due to low light conditions.

Table E-2. Summary of marine mammal sightings (number of sightings/number of animals) in the Navarin Basin, January 1986.

Flight No.	Date	Bowhead	Belukha	Walrus	Bearded Seal
E-2	23 Jan	2/6	1/14	29/501	1/2
E-3	24 Jan	3/3	1/12	2/66	0
E-4	27 Jan	11/26	1/2	2/9	0
E-5	28 Jan	0	0	0	0
E-6	31 Jan	2/3	0	0	0
Total		18/38	3/28	33/576	1/2

Prior to turning south at 61°01'N, 171°55'W another sonobuoy was dropped. This buoy transmitted numerous loud whale calls of somewhat less intensity than those from the previous buoy. The ice at this location was 90 percent large pan.

From 60°43'N, 171°50'W to 60°28'N, 171°49'W, 75 walrus were seen in groups of 4 to 40 on small pan ice (Figure E-10: leg 3). The ice edge was located at 60°19'N, 171°52'W. From the ice edge south to 58°00'N, 171°56'W (the southern turning point), sea states ranged from Beaufort 1 near the ice edge to Beaufort 5 in the open seas, with visibility of 10 to 18 km.

At 58°00'N, 171°56'W the track turned west (Figure E-10: leg 4) toward the turning point located at 58°00'N, 172°27'W. On the northern transect leg (Figure E-10: leg 5) the first sighting was of ten walrus at 60°22'N, 172°16'W, just northeast of St. Matthew Island in 70 percent new ice, large pan. Along the northern shore of St. Matthew Island there was an area of new ice, consisting of small pan, which was broken and refrozen; this ice formed an ice barrier along the island's north shore. North of the ice, open water was present for approximately 18 km. The ice edge on leg 5 was located at 60°38'N 172°19'W.

Four walrus were seen at 60°47'N, 172°18'W in 9/10 new ice, as the track approached the next turning point, located at 60°59'N, 172°20'W. At this position the ice makeup was 90 percent small to medium pan, with the open water areas covered with grease ice. A sonobuoy dropped at 61°00'N, 172°24'W transmitted numerous and loud whale calls.

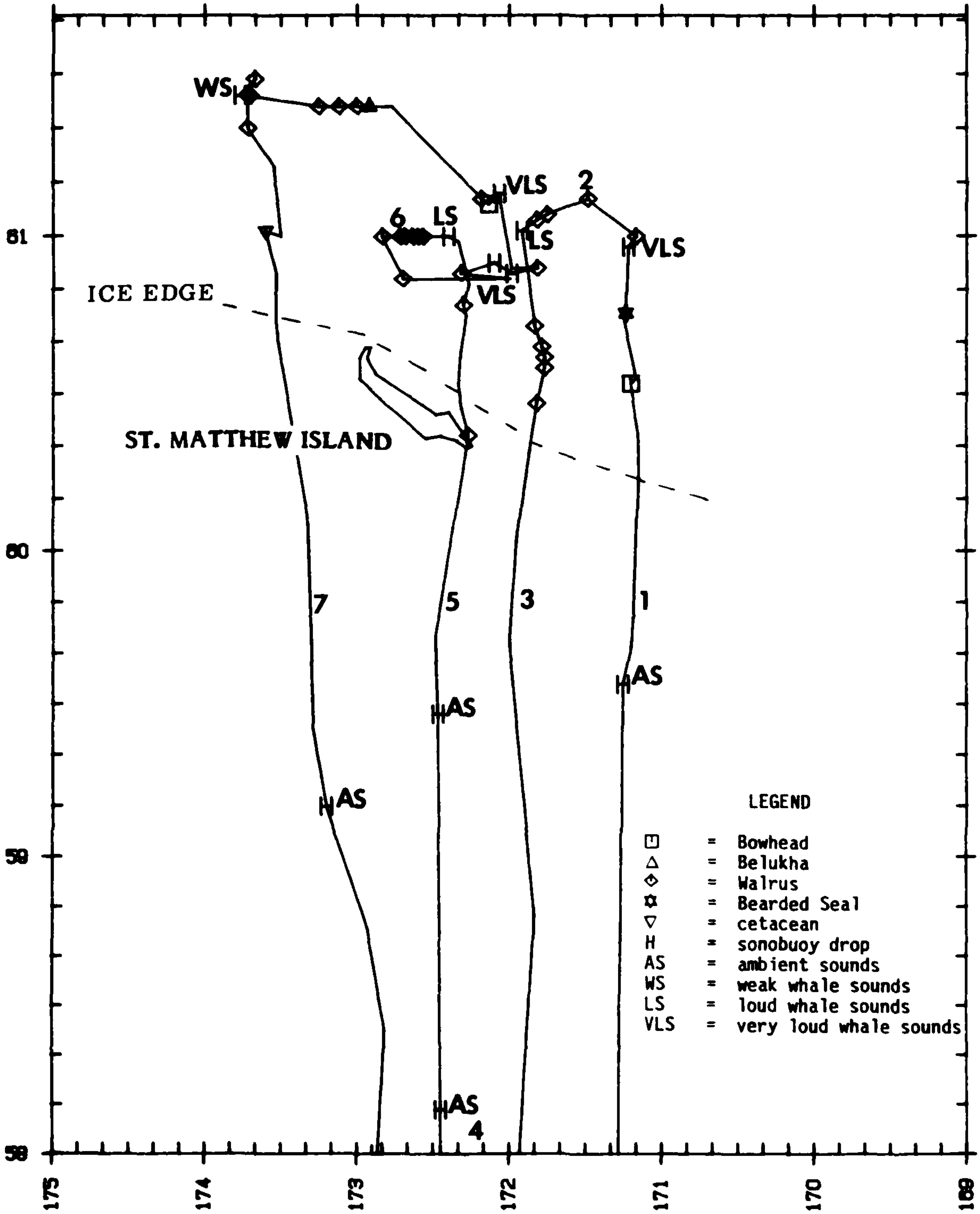

Figure E-10. Flight track for flight E-2, 23 January 1986.

The next track (Figure E-10: leg 6) proceeded west toward 61°00'N,172°50'W. On this short connecting leg 170 walrus were seen in groups ranging from 1 to 60 animals in 90 percent small to medium pan ice. At 61°00'N, 172°50'W the line transects were terminated to conduct a search survey of the area before concluding our last southerly leg.

The search survey ranged from approximately 60°50'N to 61°30'N and approximately 172°W to 173°30'W. The general ice conditions in this region were 70 to 90 percent small to medium new pan ice.

Two sonobuoys were dropped in the area of 60°55'N, 172°06'W, and both buoys transmitted numerous loud whale calls. Two sound-direction-finding sonobuoys were then dropped to obtain a bearing on the location of the whales producing the most numerous and loudest calls. The first sound-direction-finding buoy was dropped at 60°53'N, 171°59'W. It transmitted numerous loud whale calls and gave a bearing of 300°T toward the sounds. Proceeding on this heading, a second direction-finding buoy was dropped at 61°08'N, 172°04'W in 90 percent new giant pan. It transmitted very loud sounds, so loud that they overloaded the sonobuoy. Because of the overload on this buoy, it was assumed that we were quite close to the whales.

A search of the area near the last sonobuoy located five bowheads approximately four km southwest of the buoy at 61°06'N, 172°08'W. The whales were resting just below the surface, apparently involved in mating activities as they were tightly bunched together. The ice conditions were 90 percent giant pan, with the whales located on the northern edge of a small polynya. The whales responded to the aircraft on the third pass and dove.

After this sighting the search track proceeded west. Fourteen belugas were seen at 61°24'N, 172°55'W in 90 percent new ice, moving slowly north.

Another sonobuoy, dropped at 61°26'N, 173°46'W, produced weak whale calls, indicating that we had passed to the west or northwest of the majority of the whales.

Turning on the last transect line at 61°00'N, 173°30'W (Figure E-10: leg 7) and proceeding south, the ice conditions were 50 percent coverage. The ice edge was located at 60°44'N, 173°32'W and consisted of 40 percent small broken pan ice.

From this point south open water prevailed, with sea states building from a Beaufort 1 near the ice edge to Beaufort 4 as we progressed south. Visibility was intermittently reduced to less than 10 km with patchy fog.

The last sonobuoy was dropped at 59°10'N, 173°12'W and picked up no sounds other than ambient sea noise. This was true for all the sonobuoys dropped on the southern portion of each transect over the open seas.

Survey Summary

Six bowheads were located during this survey. The first sighting was during a random transect leg flown at 91 m (300 ft) of a single whale located at 60°32'N, 171°12'W. The whale was lying stationary next to the ice edge in a small polynya surrounded by 90 percent small broken pan ice. The second sighting was during a search survey flown at 73 m (240 ft) of a group of five whales located at 61°06'N, 172°08'W. The whales were apparently mating along the northern edge of a small polynya, with ice conditions of 90 percent giant pan.

During this survey, sonobuoys indicated numerous whales were located north of the ice edge from 60°30'N to 61°10'N and 171°00'W to 172°30'W.

The overall ice conditions consisted of young ice ranging from small pan to vast floe. The relative position of the ice edge is shown as an east to west dashed line in Figure E-10.

24 January 1986

Flight E-3 began at 58°00'N, 175°35'W (Figure E-11: leg 1) with a sea state of Beaufort 6 and visibility of less than two km. The first sonobuoy was dropped at 60°48'N, 175°44'W and transmitted ambient sea noises only. Proceeding north the ice edge was encountered near 61°29'N, 175°37'W. As the track turned east, a sonobuoy dropped at this location transmitted only ambient sea noise.

The connecting leg (Figure E-11: leg 2) paralleled the ice edge to 61°27'N, 175°05'W where the track turned south. A sonobuoy dropped at 60°53'N, 175°09'W (Figure E-12: leg 3) in a Beaufort 5 sea state picked up only ambient sea noises.

The track turned east at 60°30'N, 175°13'W (Figure E-11: leg 4) then north at 60°30'N, 174°51'W (Figure E-11: leg 5). The sea state, remained at Beaufort 5-6 with variable visibilities in and out of low fog. A sonobuoy was dropped on the northern end of leg 5 as the track turned east at 61°30'N, 174°45'W (Figure E-11: leg 6). The track was now about 18 km north of the ice edge. A second buoy was dropped as the track turned south at 61°30'N, 174°11'W (Figure E-11: leg 7).

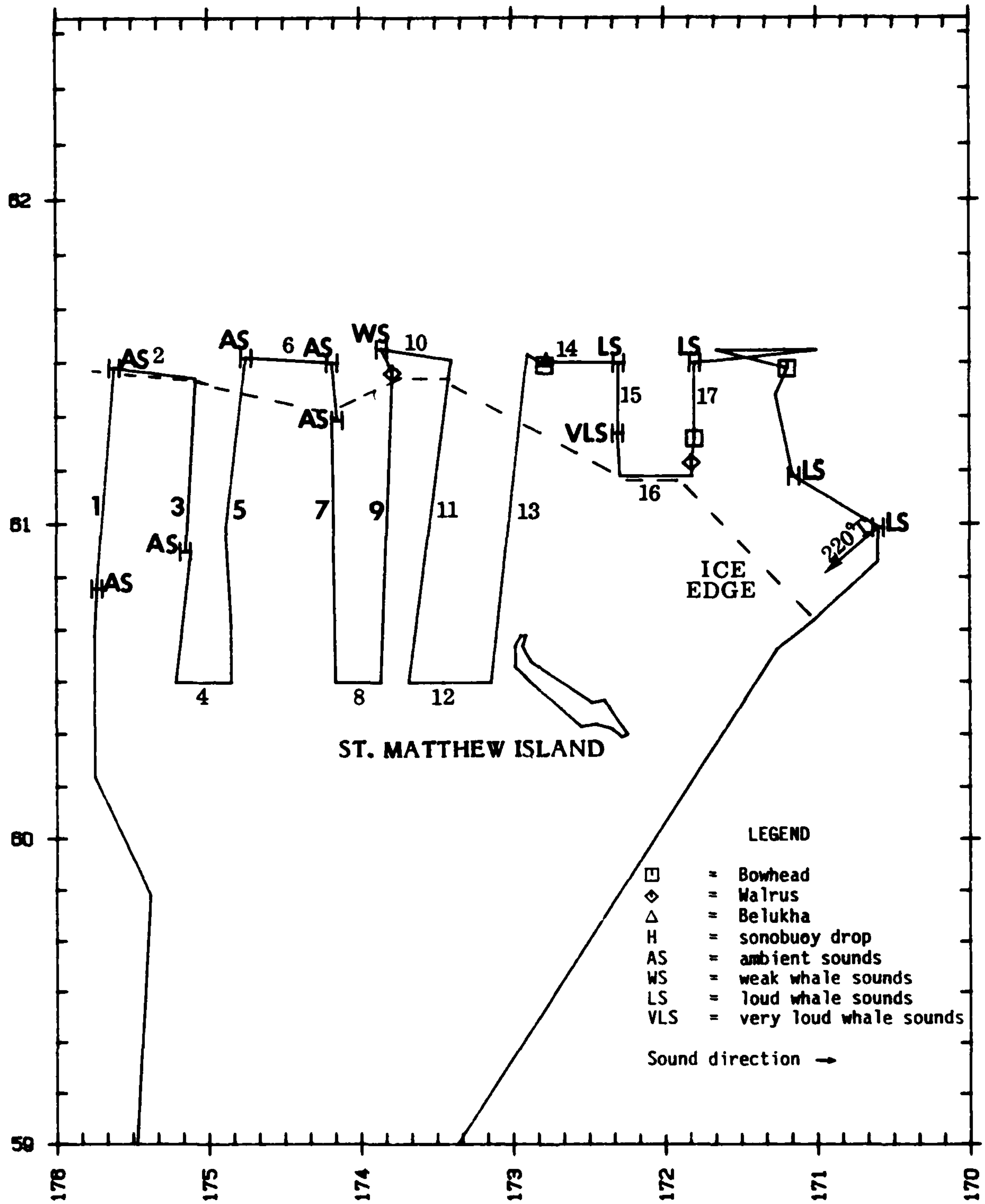

Figure E-11. Flight track for flight E-3, 24 January 1986.

both buoys transmitted ambient sea noise only. A third sonobuoy was dropped near the ice edge at 61°19'N, 174°09'W as the track proceeded south on leg 7, and again only ambient sea noise was heard.

The track turned east at 60°30'N, 174°10'W (Figure E-11: leg 8) and then north at 60°30'N, 173°52'W (Figure E-11: leg 9). The sea state remained a Beaufort 5, with visibility of about two km. A group of walrus accounting for 65 animals was seen just inside the ice edge at 61°28'N, 173°47'W in 90 percent broken small pan ice.

A sonobuoy was dropped as the track turned east at 61°32'N, 173°51'W (Figure E-11: leg 10) in 90 percent broken small pan ice. This buoy transmitted weak whale calls, and indicated that the survey was working toward whales located farther to the east, as all the other buoys picked up only ambient sea noise.

The track turned south at 61°30'N, 173°24'W (Figure E-11: leg 11) in 90 percent small broken brash ice, near the ice edge.

Sea state increased to Beaufort 5-6 as the track moved away from the ice edge. The track turned east at 60°30'N, 173°41'W (Figure E-11: leg 12) and then north at 60°30'N, 173°08'W (Figure E-11: leg 13). Sea state and visibility had deteriorated to a point where it was considered meaningless to continue the survey south of the ice edge.

The track turned east at 61°31'N, 172°54'W (Figure E-11: leg 14) in 90 percent small and medium pan ice. Two sonobuoys dropped at this position hit the ice.

Twelve belukha and one bowhead were seen on this connecting leg at 61°29'N, 172°47'W in 90 percent small and medium pan ice. The bowhead was lying stationary next to a small ice pan and responded to the aircraft, which was at 168 m (550 ft), by diving. The belukha were swimming slowly northwest. The track turned south at 61°30'N, 172°18'W (Figure E-11: leg 15). The ice coverage was 90 percent medium pan ice. A sonobuoy dropped at 61°17'N, 172°18'W in medium pan ice transmitted loud whale sounds.

The ice edge, consisting of brash and grease ice, was located at 61°09'N, 172°17'W. The track turned east near the ice edge (Figure E-11: leg 16), due to the high sea states and low visibility conditions to the south.

The final transect proceeded north at 61°09'N, 171°49'W (Figure E-11: leg 17). Ice coverage was 90 percent medium pan, all frozen together. One walrus was

seen at 61°11'N, 171°49'W in 90 percent medium pan ice, followed by one bowhead at 61°16'N, 171°48'W. This whale was resting in a small crack in 90 percent giant floe ice and responded to the aircraft, which was at 244 m (800 ft), by diving.

Visibility to the northeast was unlimited, with low patchy fog to the southeast. At 61°30', 171°48' the line transects were terminated in favor of a search survey. A sonobuoy dropped at the above position transmitted loud bowhead calls in ice conditions that were 90 percent giant floe.

One bowhead apparently resting was seen at 61°29'N, 171°12'W in 70 percent medium to large pan ice; this whale responded to the aircraft, which was at 198 m (650 ft), by diving.

After this sighting the flight continued south and another sonobuoy was dropped at 61°09'N, 171°09'W in 80 percent small pan ice. This buoy also transmitted loud bowhead calls.

A sound direction locating buoy was dropped at 60°59'N, 170°36'W in 90 percent small pan ice. This buoy transmitted loud bowhead calls, and provided a bearing indication toward the sounds of 222°T. The flight proceeded southwest on a course of 220°T (Figure E-11: arrow). At 60°53'N, 170°36'W a large lead was oriented east to west in 80 percent medium pan ice. A short search of this area was unproductive.

The survey continued southwest in diminishing light conditions. The ice edge was located at 60°42'N, 171°01'W. The survey was terminated at 60°36'N, 171°16'W.

Survey Summary

Three bowheads were located during this survey. The first whale was seen at 61°29'N, 172°47'W lying stationary in 90 percent small and medium pan ice. The second whale was located at 61°16'N, 171°48'W, lying stationary in a small crack in 90 percent giant floe. The final sighting of the day was of one whale located at 61°28'N, 171°11'W again lying stationary in 70 percent medium to large pan ice. The first two whales were seen during a line transect survey, and the third during a search survey. All three whales responded to the aircraft by diving.

The sonobuoys indicated that there were whales located east of the survey area (east of 174°W) as number and level of whale calls increased as the survey proceeded east.

The last sonobuoy, a direction-finding buoy, indicated that the majority of whale calls were located to the southwest, or toward the ice edge.

The overall ice conditions seen were of young ice or new ice, ranging from small pan to vast floe.

27 January 1986

Flight E-4 was another attempt to survey the shelf break regions from 58°N to 60°W and west to 178°30'W. Severe weather conditions with winds of 45 knots, 15 to 18 foot seas and visibilities of less than one mile, precluded working this area. An alternate survey area was located near the ice edge, where consistently better weather seemed to prevail.

The first northern leg began at 61°02'N, 173°36'W (Figure E-12: leg 1). A sonobuoy was dropped at 61°21'N, 173°36'W, and weak whale calls were heard. Although no ice was present at this location, ice was in sight an estimated 18 km ahead. The sea state was a Beaufort 4 to 5 with good visibility. Another sonobuoy was dropped just north of the ice edge at 61°30'N 173°42'W and loud whale calls were heard. Ice conditions were 40 percent small broken floe. Continuing north on leg 1, one bowhead was seen lying stationary at 61°46'N, 173°44'W in ice conditions of 40 percent small floe. This whale responded to the aircraft, which was at 305 m (1000 ft), by diving.

At 62°00'N 173°40'W the track turned east (Figure E-12: leg 2) over 100 percent newly frozen small pan ice. Two more bowheads were seen at 62°00'N, 173°24'W in 70 percent small broken pan ice, which had refrozen. Again both whales responded to the aircraft, which was at 183 m (600 ft), and dived.

Turning south (Figure E-12: leg 3), the ice edge was located at 61°22'N, 173°14'W. Visibility was unlimited with a sea state of a Beaufort 2.

At 61°00'N, 173°11'W the track turned east (Figure E-12: leg 4) in a sea state of Beaufort 4 with unlimited visibility.

The next northern leg began at 61°00'N, 172°51'W (Figure E-12: leg 5). A sonobuoy dropped at this position transmitted only ambient sea noise. Continuing north, 30 percent brash ice was encountered at 61°12'N, 172°46'W. As the ice was approached the sea state calmed to a Beaufort 2.

A suspected sighting was confirmed by circling at 61°12'N, 172°46'W when two belukhas were observed moving slowly north. A sonobuoy dropped at 61°15'N, 172°44'W, five km north of the belukha position, transmitted only ambient sea noise.

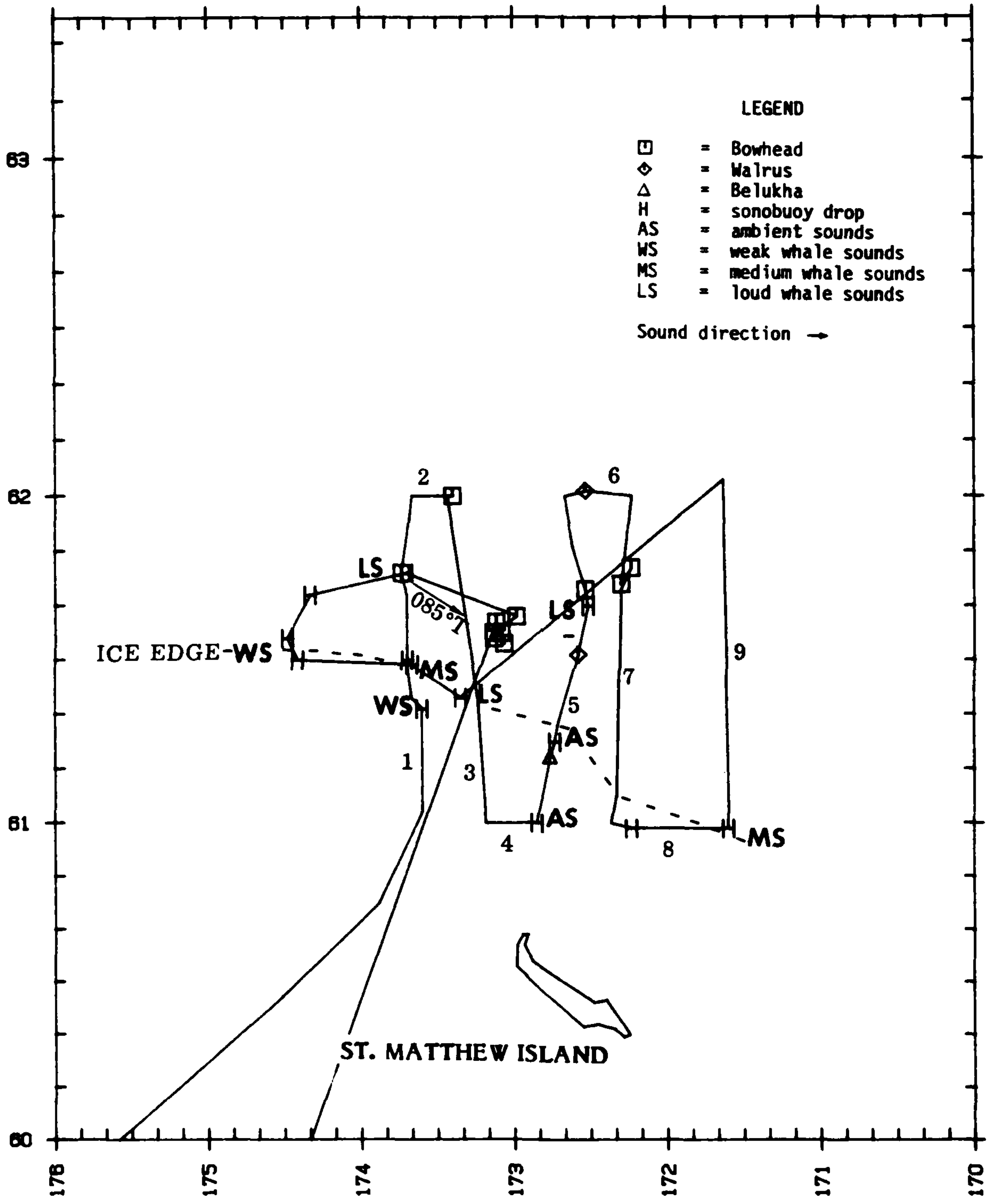

Figure E-12. Flight track for flight E-4, 27 January 1986.

Continuing north, seven walrus were located at 61°31'N, 172°35'W in 70 percent small pan ice. A sonobuoy dropped north of the walrus position at 61°40'N, 172°31'W transmitted loud whale sounds.

Four bowheads were seen on track 5 at 61°43'N, 172°32'W in 50 percent new pan ice. These whales appeared to be moving slowly north and no response to the aircraft, which was at 244 m (800 ft), was noted.

The track turned east at 62°00'N, 172°40'W (Figure E-12: leg 6) over 70 percent to 100 percent new ice. Two walrus were seen on this connecting leg at 62°01'N, 172°32'W in 70 percent small pan ice.

At 62°00'N, 172°14'W the track turned south (Figure E-12: leg 7) in 40 percent new ice. One bowhead was seen on line at 61°44'N, 172°18'W lying motionless next to a small ice pan, in 60 percent small floe conditions. This whale responded to the aircraft by diving. While circling the area a second bowhead was seen at 61°47'N, 172°14'W. This whale was traveling south in 70 percent small new pan ice conditions. No aircraft response was noted. The ice edge on leg 7 was located at 61°05'N, 172°20'W with 20 percent grease ice and increasing sea states of Beaufort 3-4.

The track turned east at 61°00'N, 172°22'W (Figure E-12: leg 8) with visibility unlimited and a Beaufort 5 sea state.

A sonobuoy was dropped at 60°59'N, 171°36'W as the track turned north, with 20 percent small broken floe ice conditions, a sea state of Beaufort 3 and visibility unlimited (Figure E-12 leg 9). This buoy transmitted medium-loud whale calls.

This final northerly leg was primarily over 100 percent new ice with very little open water. At 62°03'N, 171°38'W, the line transects were terminated in favor of a search survey on a southwest heading.

At 61°23'N, 173°21'W a sonobuoy was dropped near the ice edge. This sonobuoy transmitted loud bowhead calls. A second sonobuoy equipped with sound-direction-finding capabilities was dropped at 61°29'N, 173°40'W. This sonobuoy transmitted medium-loud whale calls, and provided a bearing of 085° true toward the north-east. Two more direction-finding buoys were dropped, one at 61°34'N, 174°29'W and the other 61°46'N, 173°42'W. The latter sonobuoy provided a bearing of 110°T toward the general area of 61°35'N, 173°00'W, the area producing the majority of whale calls.

The first whale seen on the search survey was located at 61°38'N, 172°59'W lying stationary in 10 percent small pan ice. This sighting was followed by two whales at 61°35'N, 173°08'W in 70 percent new ice.

Six bowheads were seen at 61°35'N, 173°05'W, resting in small holes within 70 percent new ice, and small pan ice. Six more whales were located at 61°34'N, 173°08'W lying stationary in 70 percent small pan, and grease ice, approximately 2 km south of the previous sightings, followed by one bowhead stationary at 61°33'N, 173°04'W in 70 percent new ice. The last whale was seen at 61°37'N, 173°07'W in 70 percent new ice and medium pan ice, lying motionless. The search survey was terminated at 61°33'N, 173°10'W due to darkness.

Survey Summary

The majority of whales seen on this flight were located during the search survey, in the central area of 61°35'N, 173°00'W, approximately 18 km north of the ice edge. However, acoustic information indicated that whales were present across the entire survey area. Most were individually resting in small holes or polynyas apparently taking advantage of the calm water provided by the ice.

The whales sighted during the search portion of the survey were extremely difficult to see or relocate due to the decreasing light conditions, and were generally observed only briefly during a single pass. Because of this, aircraft responses were not confirmed for these sightings. All of the whales seen on the search survey appeared to be resting.

28 January 1986

Flight E-5 was an attempted survey of the area between 58°N to 60°N west of 178°W. After one line from 58°N to 60°N, it was evident that waves of 17 to 18 feet and winds gusting to 45 knots made surveys in this region impossible.

Our optional or secondary survey area was again located near the ice edge. Transects began at 60°45'N, 177°45'W (Figure E-13: leg 1) when a sonobuoy was dropped into a Beaufort 5-6 sea, with visibility of about 10 km. This sonobuoy transmitted only ambient sea noise. At 61°32'N, 177°11'W on leg 1 a second sonobuoy was dropped; again the only sounds heard were ambient sea noises.

At 61°51'N, 176°58'W (Figure E-13: leg 1) another sonobuoy was dropped, again transmitting only ambient sea noises. Visibility was about 18 km in a sea state of Beaufort 5, with no ice in sight.

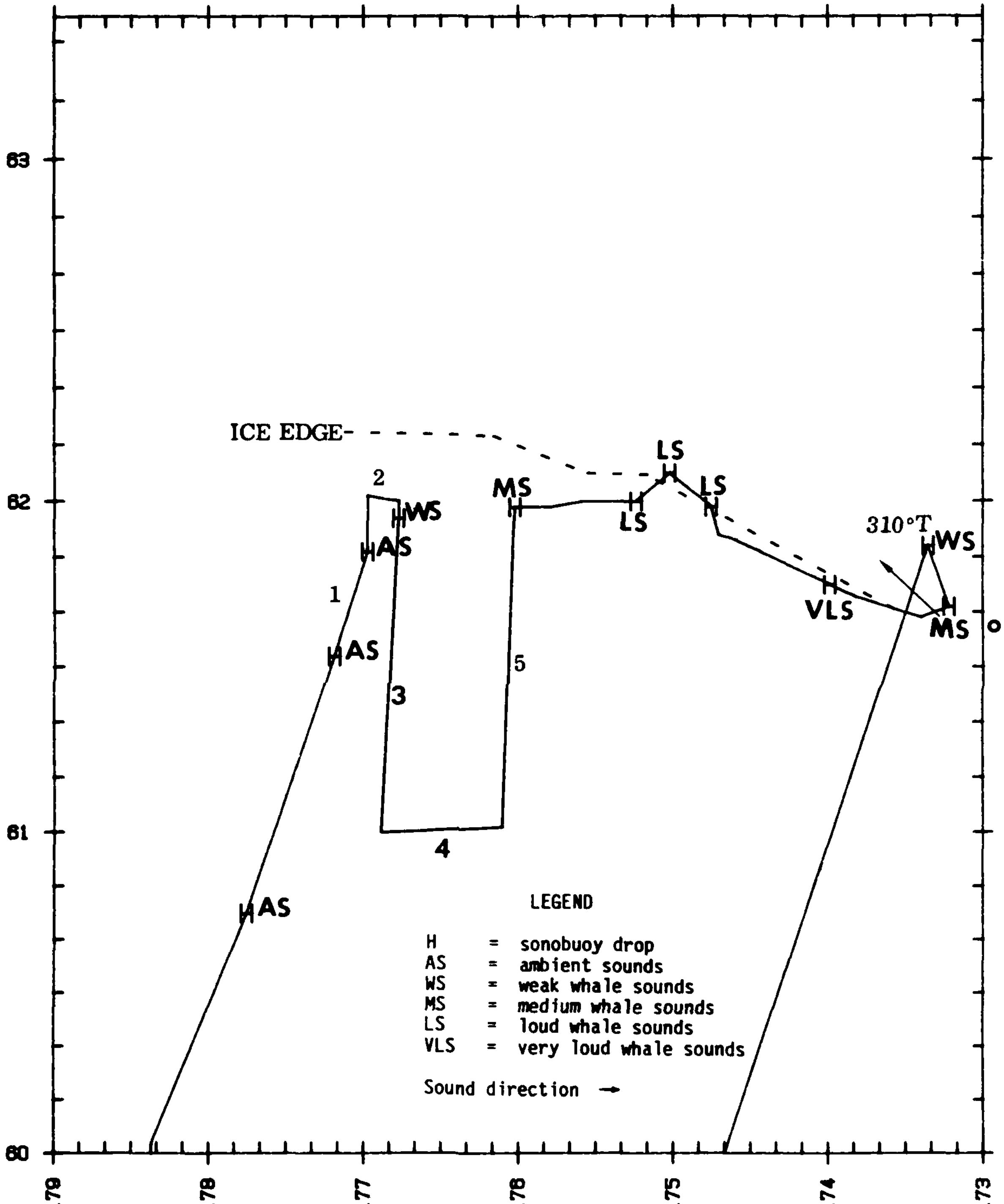

Figure E-13. Flight track for flight E-5, 28 January 1986.

The northern turning point was located at 62°01'N, 176°58'W. This connecting leg (Figure E-13: leg 2) headed east, then proceeded south at 62°00'N 176°46'W (Figure E-13: leg 3). Conditions were open water, with the ice edge barely visible to the north.

A sonobuoy dropped at 61°57'N, 176°46'W (Figure E-13: leg 3) transmitted weak whale calls masked by high sea state noise. The southern portion of the leg was uneventful; sea state continued to be Beaufort 5 to 6 with visibility less than 7 km in patchy fog.

At the southern turning point of 61°00'N, 176°53'W the track proceeded east to 61°01'N, 176°06'W (Figure E-13: leg 4), then turned north (Figure E-13: leg 5) with sea states of Beaufort 5-6 and visibility of less than 10 km with haze.

Upon reaching the northern turning point of leg 5 a sonobuoy was dropped at 61°59'N, 176°01'W. This sonobuoy transmitted whale calls that were somewhat louder than those heard from the last buoy, indicating that we were moving toward the whales location. The ice edge was in sight to the north of this position. Weather and sea conditions to the south were considered unacceptable for continuing the survey over the open water. Because of this, the line transects were terminated at 61°59'N, 176°01'W. The search survey proceeded northeast toward the ice edge located at 62°05'N, 175°00'W. Two sonobuoys were dropped, one at 62°05'N, 175°00'W and the other at 61°59'N, 174°45'W, and loud whale calls were heard. The search track now followed the ice edge toward the southeast. Another sonobuoy was dropped at 61°45'N, 173°59'W in 50 percent small pan ice, and very loud whale sounds were heard (compared with the other buoy drops) indicating that we were quite close to the whales.

Two sound-direction-locating sonobuoys were dropped. The loudest signal came from the one dropped at 61°41'N, 173°13'W and gave a 310°T bearing toward the whale sounds. The other buoy dropped at 61°52'N, 173°21'W transmitted weak, nondirectional sounds. The 310°T bearing indicated that the whales were located to the west of the buoy position, most probably near the buoy dropped at 61°45'N, 173°50'W that transmitted very loud sounds. Reduced light conditions forced the termination of the survey before the whales could be located.

Survey Summary

No sightings were made on this flight. Sonobuoys indicated considerable acoustic activities from the whales in the eastern regions of the survey area.

31 January 1986

Flight E-6 surveyed the region south of St. Lawrence Island starting east of Northeast Cape at 63°00'N, 167°56'W and working to the west. The ice conditions at the starting point, 63°11'N, 167°56'W (Figure E-14: leg 1) were 90 percent old annual ice with small polynyas.

The first sonobuoy was dropped on leg 1 at 63°20'N, 168°22'W in 90 percent ice; this sonobuoy transmitted ambient noise only. The second sonobuoy was dropped on Leg 1 at 62°21'N, 168°23'W and transmitted loud biological sounds possibly originating from walrus. Weak whale calls were occasionally heard in the background.

Two bowheads were seen at 62°20'N, 168°17'W, while the aircraft moved off leg 1 to drop a sonobuoy in one of the few open polynyas available. This sonobuoy transmitted only ambient sea noise. The whales were resting in a small polynya and responded to the aircraft, which was at 152 m (500 ft), by diving in ice conditions that were 90 percent old medium floe.

At 61°39'N, 168°28'W the track turned west (Figure E-14: leg 2) crossing 90 percent ice to 61°40'N, 169°33'W. Visibility was approximately 6 km with low ceilings.

Proceeding north (Figure E-14: leg 3), another sonobuoy was dropped at 62°06'N, 169°26'W in 80 percent annual ice. No sounds were heard from this sonobuoy.

At 62°48'N, 169°21'W the track turned west (Figure E-14: leg 4) over 90 percent ice with visibility reduced to one km and fog.

As the track turned south at 62°47'N, 170°36'W (Figure E-14: leg 5), we found that the ice conditions had changed greatly in this region. The entire area was 90 percent very new ice, covered with light snow. Open water areas consisted of small melt holes in the new ice. Visibility had improved to 2 km and fog.

At 61°39'N, 170°49'W the track turned west (Figure E-14: leg 6) and at 61°40'N, 171°00'W turned north (Figure E-14: leg 7) over 90 percent new ice with numerous small melt holes.

A sonobuoy dropped at 62°01'N, 171°00'W on leg 7 transmitted loud bowhead calls, indicating quite a number of whales in the area. We terminated the transect survey at 62°13'N, 171°01'W and proceeded to search the areas of open water and small melt holes, under visibility conditions of less than one km.

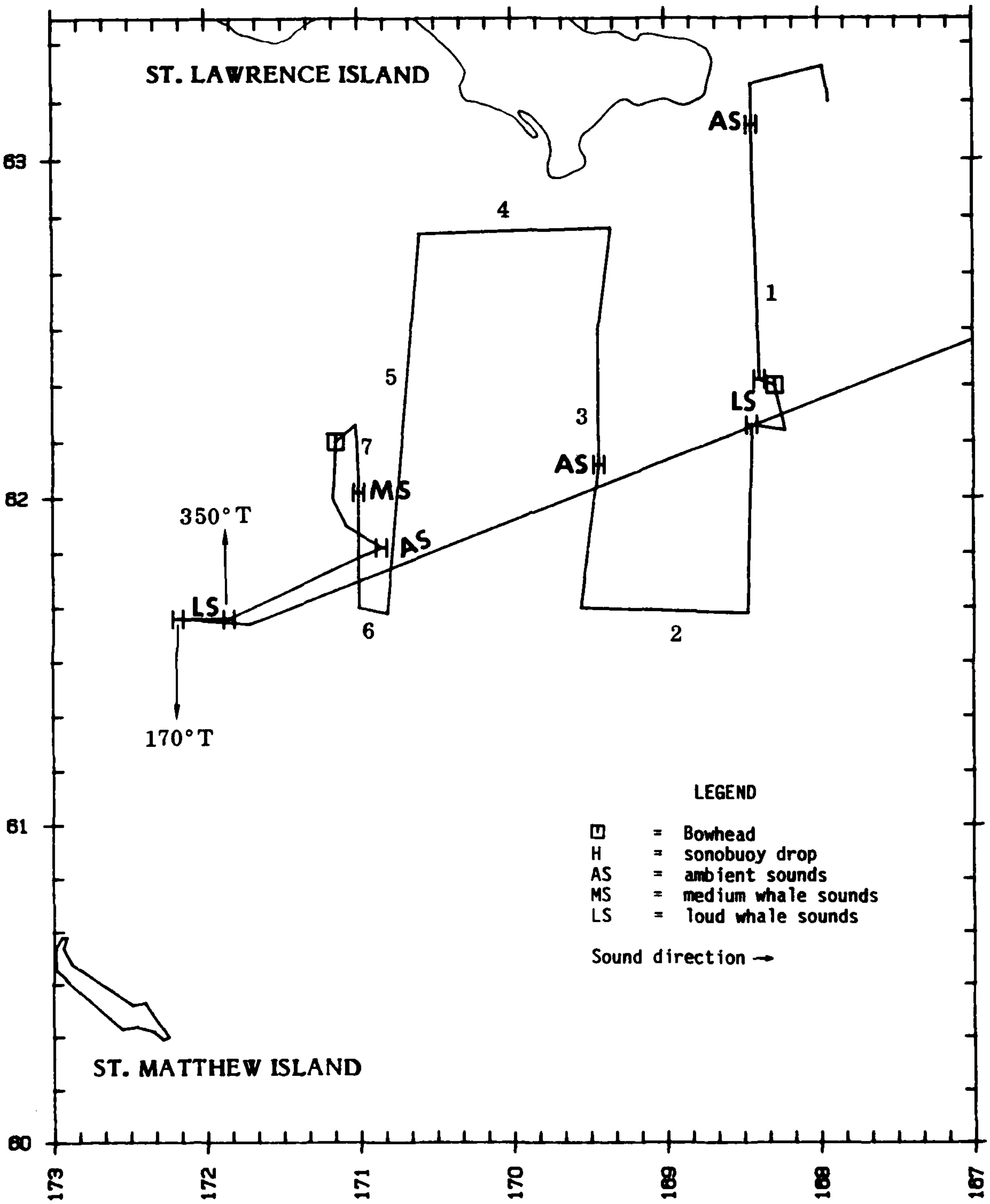

Figure E-14. Flight track for flight E-6, 31 January 1986.

One bowhead was seen at 62°10'N, 171°09'W. This whale was resting in a small melt hole and responded to the aircraft on our third pass by diving under 90 percent new ice.

Another sonobuoy was dropped at 61°51'N, 170°51'W in 80 percent ice, 50 percent new medium floe and 30 percent new ice. No sounds were heard other than ambient sea noises.

Two direction-finding sonobuoys were dropped in the area of 61°38'N, 171°11'W and both transmitted loud bowhead calls. Direction indications from the first sonobuoy gave a bearing of between 350° and 020°T, while the other sonobuoy gave a direction of 170°T, indicating that the sonobuoys were locating on two groups of whales. Calls from the northern group were estimated to represent at least five whales, based on the individual calls heard. The southern group seemed to have at least three different calls or individuals represented. The ice conditions in the area of the buoy drops were 80 percent new ice broken by a large lead oriented east-west. Visibility was about 10 km and appeared to improve to the south.

Survey Summary

This survey was marginal with respect to weather and visibility conditions. Surface winds were in excess of 35 knots and patchy fog prevailed over most of the area surveyed.

Ice conditions were primarily of two types: to the east 90 percent old first-year ice of medium floe was seen, while to the west 90 percent new ice was most common. The sightings indicated that whales were distributed both to the southeast and southwest of St. Lawrence Island. This distribution is supported by acoustic data as well as the sighting data. The acoustic data also indicated that the majority of whales were located in the western regions.

DISCUSSION

Aerial surveys for endangered whales in the Navarin Basin and St. Matthew Hall planning areas were not successful in summer 1985, but were highly successful and yielded important results in winter 1985. The 1986 winter survey effort in the Bering Sea, made possible with logistic support of Navy P-3 Orion aircraft, provided aerial survey coverage of areas not previously surveyed, and gave an index of bowhead whale use of those areas during late January. The position of the marginal ice front proved to be instrumental in determining where surveys could effectively be flown since sea states in open water areas were usually too high (Beaufort 5-7) to successfully survey. In January 1986, the marginal ice edge was located approximately 18 km north of St. Matthew Island, farther to the north than in February and March 1983, and as such the 1986 effort was generally northeast of that completed by Brueggeman et al. (1984) (Figure E-15).

Flight E-2 was the only survey conducted with favorable environmental conditions over the open sea south of St. Matthew Island. All other surveys attempted in this region met with low visibilities and high sea states. One bowhead was seen on Flight E-2 approximately 33 km north of the marginal ice edge, with another sighting of 5 whales approximately 78 km north of the ice edge in an area of considerable acoustic activity (Figure E-10).

Dramatic ice movements occurred between Flight E-2 of 23 January (Figure E-10) and Flight E-3 of 24 January (Figure E-11), as the ice moved to approximately 74 km north of St. Matthew Island within a 24 hour period. Surface winds of 35-45 knots are thought to be the cause of this movement. The third flight on 24 January (Figure E-11) found whales approximately 15, 33, and 86 km north of the marginal ice edge.

Flight E-4 (Figure E-12) showed that the marginal ice edge had continued to move northward approximately 13 km from the previous ice edge location over a three day period. Numerous whales were seen on this flight distributed approximately 24 to 80 km into the marginal ice zone, with the majority found approximately 24 to 31 km south of the ice edge.

Flight E-5 (Figure E-13) surveyed areas primarily to the south of the ice edge. No whales were seen on this flight but weak sounds indicated that whales were located toward the northeast. The marginal ice edge in the eastern portion of the survey area was still further north than on previous surveys.

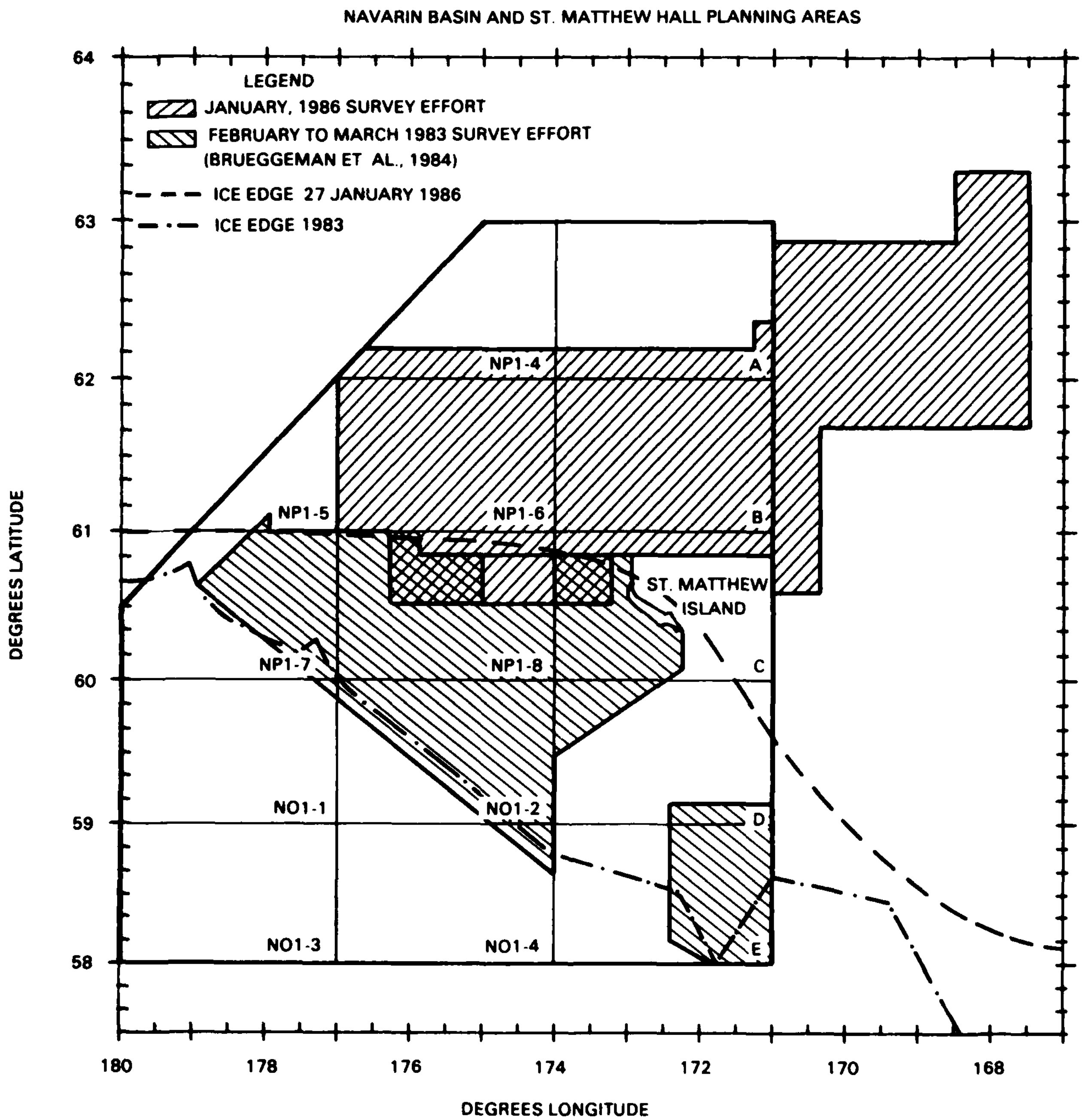

Figure E-15. Composite survey coverage of the Navarin and St. Matthew-Hall Planning Areas in February and March 1983 (Brueggeman et al., 1984), and January 1986.

Flight E-6 surveyed the area south of St. Lawrence Island (Figure E-14). Three bowheads were seen south of the island.

Bowheads appeared to move north with the moving ice edge, to stay within the marginal ice zone. The acoustic data provided by the sonobuoys supports this hypothesis, since only a few buoys detected whale sounds south of the ice edge. Sound production within the marginal ice zone seemed to be continuous, although variabilities in sound intensities did occur. On several occasions, sound intensities increased from weak to very loud, then decreased to weak sounds, then increased again to very loud sounds as the survey moved across an area. This variability in sound intensity indicated that groups of whales were being acoustically but not visually detected as the survey moved across an area and illustrated the importance of acoustic data in the Bering Sea.

Most bowheads seen were in leads or polynas within the marginal ice edge. Little or no water disturbance was evident during all sightings, including that of a group of five whales involved in possible mating as they were suspended in the water column just below the surface. The lack of water disturbance may have been due to reduced activity by the whales or may have been an artifact of the poor sighting conditions due to reduced light conditions. Most whales were resting or swimming slowly in the calm water within the marginal ice zone.

The results of these surveys and those completed in 1983 (Brueggeman et al., 1984) support the contention that bowheads seem to prefer the marginal ice zone during the winter, regardless of where the zone is located. During the 1983 winter surveys, the ice edge was located south of St. Matthew Island (Figure E-15) and bowhead sightings were further south than the 1986 sightings. Regardless of the relative positions or general areas of bowhead sightings during the winter surveys, the type of ice in which whales were found was similar. Whales were seen within the marginal ice front, in ice coverage ranging from 10 to 90 percent, in both 1983 and 1986. Brueggeman et al. (1984) report that bowheads showed no specific direction of movement. Bowheads seen during the present surveys also did not appear to be swimming in any particular direction. Most were resting or swimming slowly, and the general interpretation was that the whales may have been taking refuge from the higher sea states in the open water to the south. The annual variation in ice, including formation, thickness, and concentration, may play an important part in the winter distribution of bowheads, similar to the way in which annual variation in summer and fall feeding areas play an important part in the bowhead whale fall migration.

The Orion P-3 aircraft proved to be a more than adequate survey aircraft as it provided a safe and effective platform for aerial surveying in difficult areas. Summer surveys in the Navarin Basin using Navy P-3 Orions were not successful because of schedule conflicts, and the prospects for completing summer surveys of this type in the future are not good. Further studies should work to document the existence and movements of the marginal ice edge in winter. More importantly, however, future studies should attempt to survey areas not previously covered, especially the open water areas south of the ice edge, and the heavier ice areas north of the marginal ice zone. When this data is combined with already existing Bering Sea data, a complete and comprehensive view of bowhead whale distribution and habitat use in the Bering Sea will emerge.

ACKNOWLEDGEMENTS

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